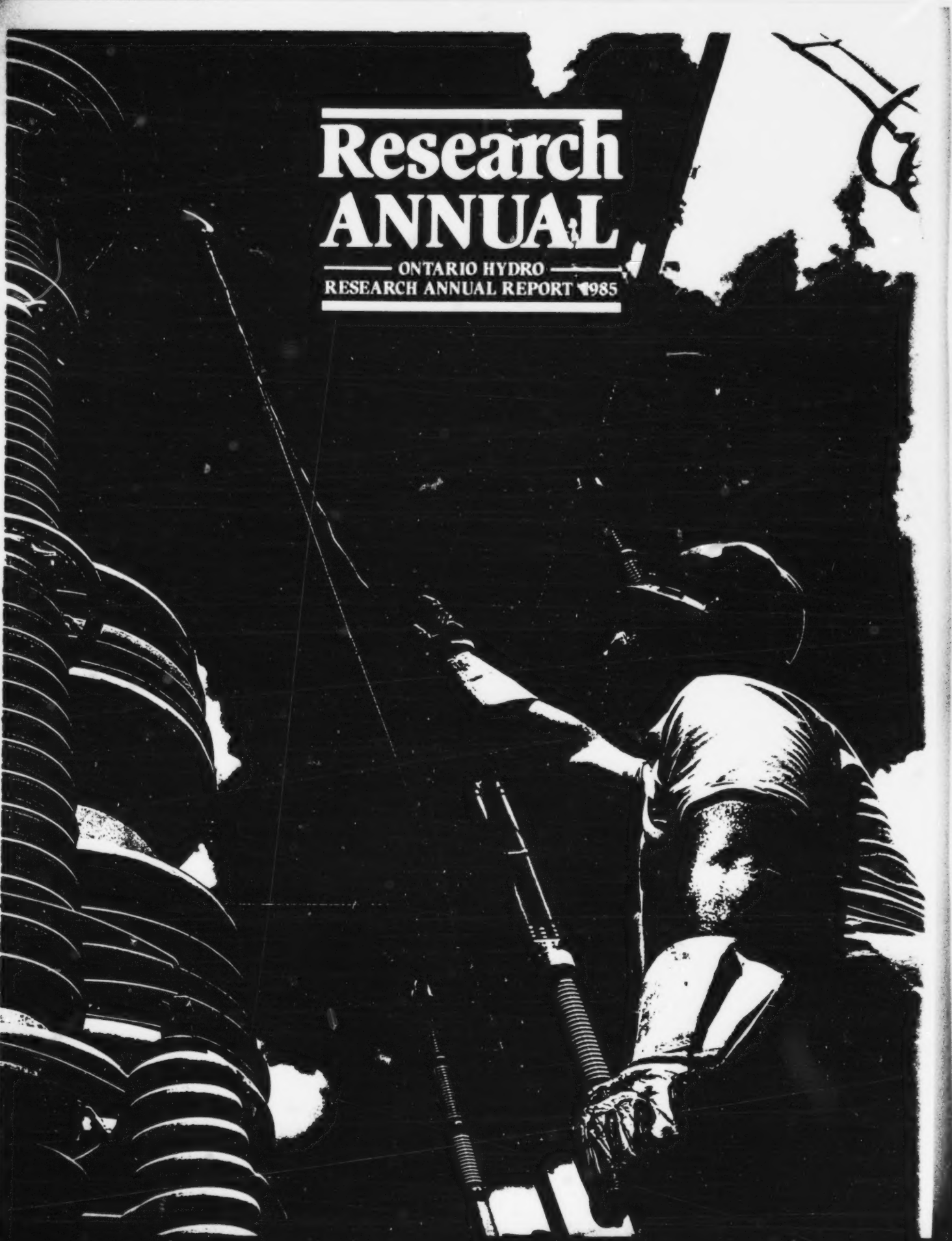
Research
ANNUAL
ONTARIO HYDRO
RESEARCH ANNUAL REPORT 1985

The photo shows a mobile 700-kV resonant reactor system and its voltage divider being prepared for overvoltage tests to verify the integrity and reliability of SF_6-insulated bus-duct and switchgear at Claireville Transformer Station. This station, located just northwest of Metropolitan Toronto, is a key point in Ontario Hydro's growing 500-kV transmission system that carries power from large generating complexes, such as the Bruce Nuclear Power Development and the northern hydro-electric generating stations on the Abitibi and Mattagami Rivers to connections with the 230-kV system and load centres in southern Ontario.

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Contents

Vice-President's Message	4
Director's Message	5
Research Departments	6
Generation	8
Delivery Systems	18
Utilization	24
Environmental Protection	28
Resources and Costs	34
Organization	35
Publications	36
Presentations	39
Abbreviations and Acronyms	43

Vice-President's Message

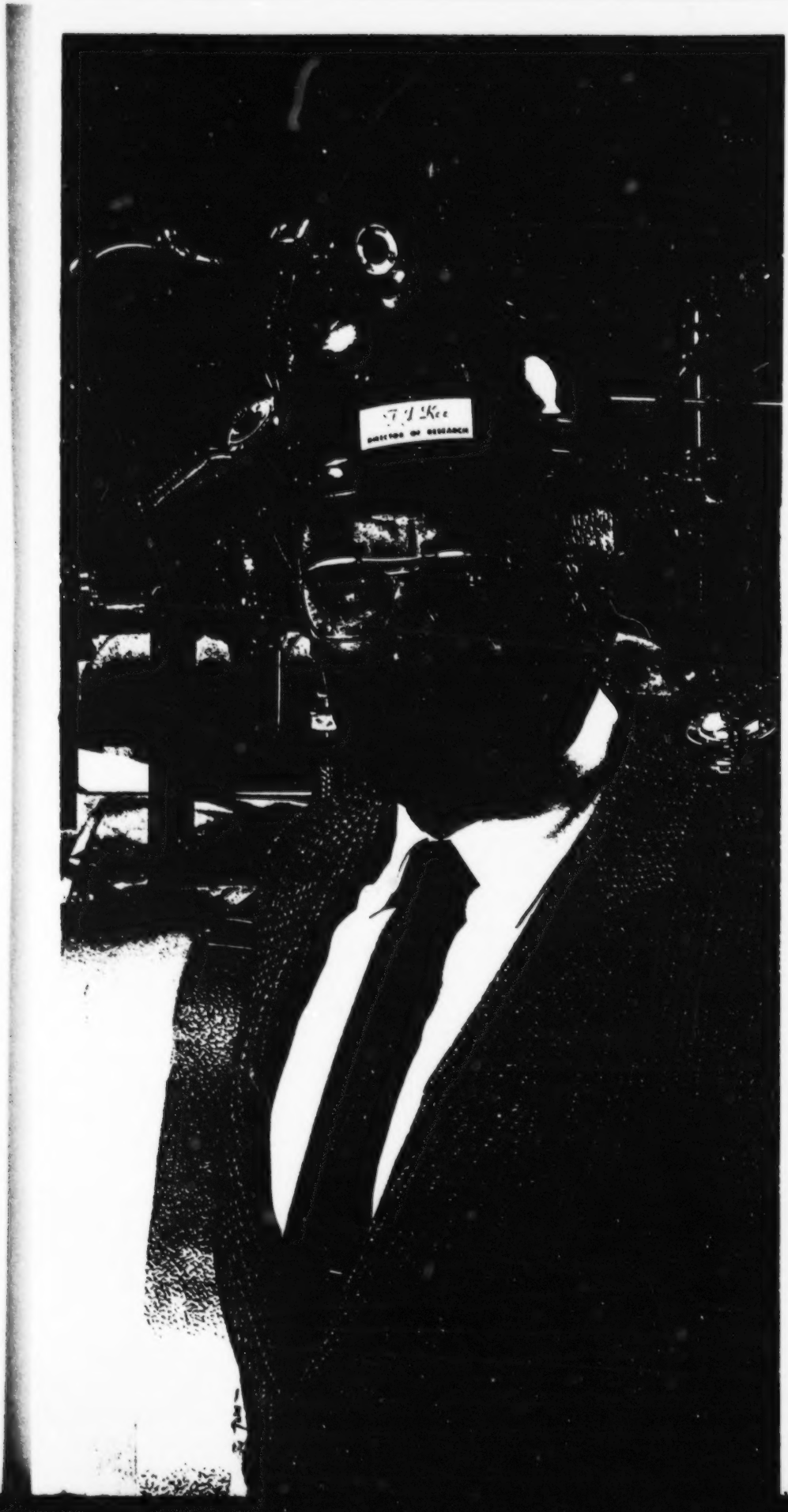
Ontario Hydro is one of the largest electrical utilities in the world and one of the best in terms of efficiency, economy and reliability. Its power system includes hydro-electric, fossil-fired and nuclear-fuelled generating stations with a total dependable capacity of 24 291 megawatts, and a delivery system that extends throughout most of the inhabited parts of the province. In 1985, the Corporation used these facilities to make available 109 million megawatt hours of electricity for distribution with the cooperation of 316 municipal utilities to about 3 165 000 ultimate customers.

Ontario Hydro does more than just maintain and operate its power system. It also undertakes much of the design and construction necessary to meet growth in requirements and to replace obsolete facilities. The Research Division provides technological leadership and support and is often involved in the development and application of devices and processes that are specifically designed to meet Ontario Hydro requirements. Many of these applications involve Ontario industry and some find markets elsewhere, creating revenue and jobs.

The transfer of technology between Hydro and industry has been going on since Ontario Hydro was founded in 1906 and has greatly benefited the province. A number of transfers in which the Research Division has participated are described in the pages that follow. One, the OH-180 programmable controller, is featured on page 44.

L. G. McConnell

L.G. McConnell
Vice-President
Power System Program



Director's Message

Nineteen eighty-five was marked by a number of events of major significance to the Research Division.

New facilities were commissioned to test, evaluate and demonstrate apparatus and processes for utilization of electricity. This aids our customers by providing a basis for decision with respect to use of new technologies that promise improvements in energy economy and product quality. Among the more important of these technologies are applications of infrared and microwave radiation for drying and heating, and the use of plasma arcs in the production of spheroidal ceramic particles suitable for sintering.

With the cooperation of the Human Resources Branch, Division management finalized development and obtained approval for implementation of a "dual ladder" concept. This provides senior scientific and engineering staff with the option of a career course that frees them to pursue technical objectives without hindrance from administrative responsibilities.

In addition, 1985 saw the establishment of an awards program intended to recognize outstanding contributions by laboratory staff in the fields of technology and management. The program commemorates the contributions of the men for whom two of the awards were named - Dr. W.P. Dobson, pioneer Director of Research, and Dr. H.A. Smith, who oversaw development of Ontario Hydro's nuclear program.

During the year the Division continued to provide the usual high calibre of support to Ontario Hydro in meeting and resolving problems encountered in the ongoing operation of the power system. I am pleased to record my appreciation of the dedication and hard work of the Division's managers and staff.

Fred. J. Kee

F.J. Kee
Director of Research

Research Departments

Support functions required for smooth operation of the Division are provided under the guidance of J.B. (Bruce) Brown, manager of the **Divisional Services Department.** These include accounting, secretarial, clerical, word processing, photographic and editorial services. Technical support is supplied by a drafting office and a model shop.

O.A. (Allan) Kupcis, manager of the **Chemical Research Department,** oversees research in the chemical, biological and environmental disciplines. Work ranges from provision of analytical chemical services to investigation of methods for control of acid rain and other pollutants.

T.W. (Tony) Klym, manager of the **Civil Research Department,** is responsible for research, testing and inspection involving soils, rock and concrete. Activities include engineering assistance in the selection of sites for new facilities, optimization of the strength and durability of concrete, and evaluation of the mechanical properties of large rock masses.

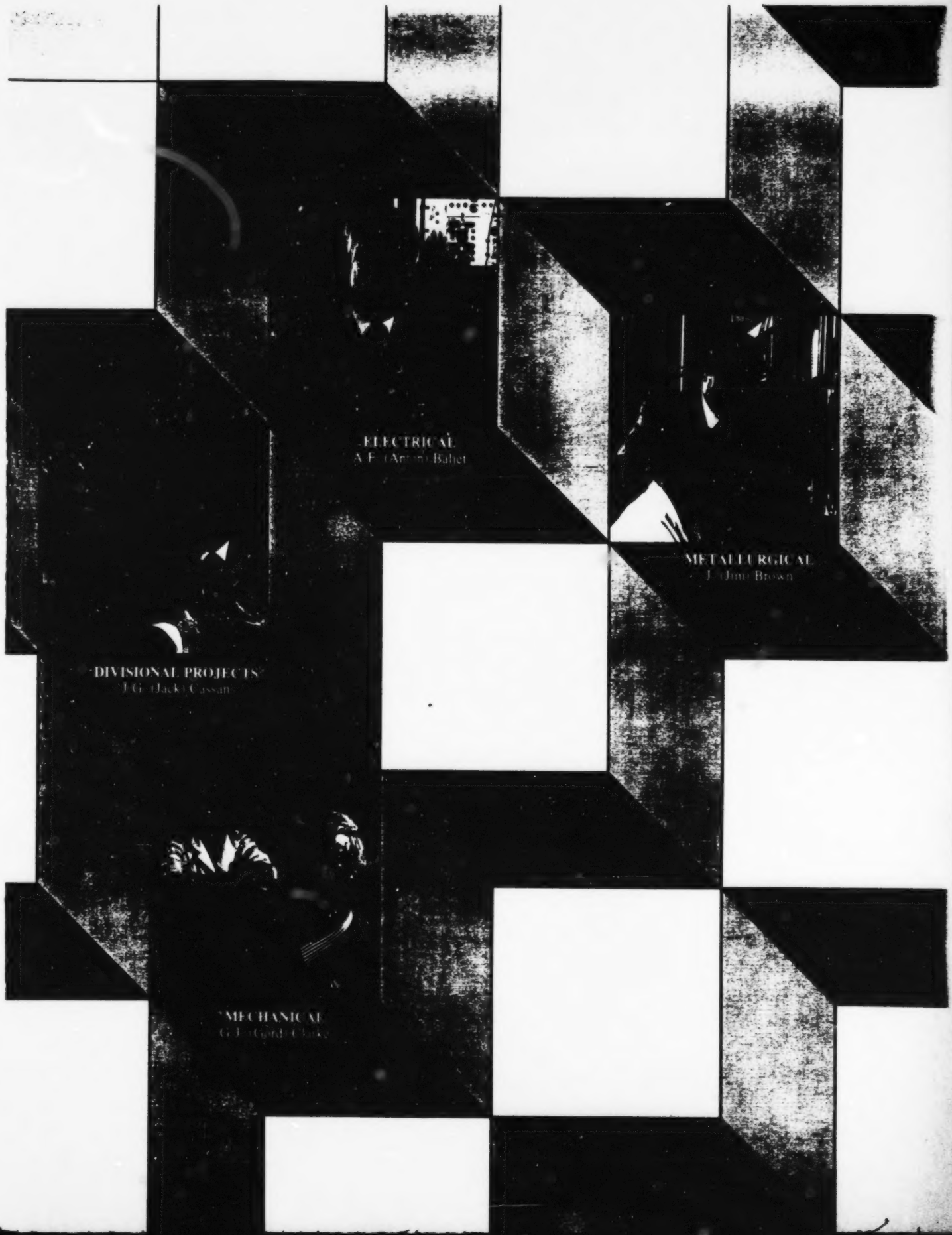
Identification of new research opportunities and initiation and coordination of research activities within the Division and in collaboration with outside organizations are two important functions of the **Divisional Projects Department** managed by J.G. (Jack) Cassan.

Mr. Cassan also acts as manager of the **Operations Research Department,** which provides consulting services to all units of Ontario Hydro in areas of operations research, statistics and reliability assessments. This Department also provides computer support services to the Division.

A.F. (Anton) Baljet manages the **Electrical Research Department.** The work of this group ranges from the solution of problems affecting the operation of the power system to studies of new and efficient uses of electrical energy. New applications of electronics in the power system are developed.

The **Mechanical Research Department,** managed by G.J. (Gord) Clarke, is responsible for improving the performance, reliability and safety of components and mechanical processes used in the generation, transmission and distribution of electricity. The work includes studies of machine dynamics, and full-scale testing and stress analyses of structural components.

Under the leadership of J. (Jim) Brown, the **Metallurgical Research Department** explores many areas of physical metallurgy and materials science. Work includes evaluation of the integrity of components in nuclear and thermal plants, corrosion studies, fracture mechanics analyses, and nondestructive testing and evaluation.


ELECTRICAL
A.F. (Antonio Ballet
METALLURGICAL
J. (Jim) Brown
DIVISIONAL PROJECTS
J.G. (Jack) Cassan
MECHANICAL
G.F. (Gord) Clarke

Generation

Ontario Hydro is fortunate to have a large, diverse and effective resource of generating facilities. In 1985, the Corporation generated 115 824 000 MW·h of electricity - 48 459 000 MW·h at nuclear stations, 29 941 000 MW·h at fossil-fired stations and 37 424 000 MW·h at hydraulic stations.

The nuclear units are of the CANDU design, and for some years they have held most of the top places for gross capacity factor among the world's large power reactors. They generate energy at low cost, their safety record is good and their radiation emissions are well below the limits set by regulatory authorities. The efforts of the Research Division are directed towards maintenance of this high degree of nuclear unit effectiveness.

Modern fossil-fired units are of large dimensions to obtain economies of scale, and a small defect can cause a large and costly power outage. The Research Division is responsible not only for helping to solve problems as they occur but also for performing studies aimed at avoiding unit failures.

In hydraulic plants, design changes have been less frequent and problems may be fewer for that reason. The main function of the Division in this area is to provide support for the maintenance and repair of existing equipment and structures.

NUCLEAR

Characteristics and Performance of CANDU Pressure Tubes

Investigation of the mechanism by which hydride blisters form on the pressure tubes of fuel channels in CANDU reactors continued in 1985. Laboratory tests and large-scale loop tests showed that hydride blisters can form on pressure tubes made of Zr-2.5wt%Nb as well as those made of Zircaloy-2, the alloy used in the pressure tube of Unit 2 at Pickering NGS that failed in 1983. A computer model was developed by the Research Division to predict the growth of blisters on pressure tubes in contact with calandria tubes at various stages of reactor life.

Full-scale tests of very large pumps and pump motors can be performed in the Division's Nuclear Process Components Test Facility.

To verify the thermal calculations of this model, an apparatus has been developed that brings a sample section of pressure tube into contact with a surrounding section of calandria tube, also made of zirconium-niobium alloy. The pressure tube is deformed as necessary to provide the desired area of contact. Reactor operating conditions are simulated by circulating oil at about 300°C on the primary side and water at 60°C on the secondary side. A technique which permits installation of thermocouples in small-diameter holes as close as 0.127 mm to the contact surface has been developed and used. This allows measurement of transient and steady-state temperatures with minimal effects on the thermal field.

Blister formation, however, is only one aspect of the integrity assessment. It is necessary to know also if the blisters will initiate cracks. Studies are therefore in progress to establish the stress levels at which cracks will initiate from blisters of various sizes.

The extent of pressure-tube calandria-tube contact and the amount of hydrogen in the bulk of the pressure tube, which depends on operating time and rate of corrosion, are of primary importance in blister formation. Extensive study of Zr-2.5wt%Nb was initiated as there is little available information on the corrosion characteristics of this alloy. Post-service examinations of pressure tubes are now being made at regular intervals and a computer data base has been established to record all data from this source.

Elongation of pressure tubes will require extensive maintenance in some reactors and there is a possibility that changes in reactor operating conditions could lead to an increase in deformation rate that would limit pressure-tube life. Extensive irradiation-growth tests on different Zr-2.5wt%Nb pressure-tube materials have therefore been performed in the Dido reactor at AERE Harwell, in

which the fast neutron fluence is higher than in power reactors. The results of this study indicated that there is a need for change in the predictive design equation and will provide the basis for that change.

Location and Repositioning of Fuel-Channel Spacers

Garter springs are used to maintain proper spacing between the pressure tubes and surrounding calandria tubes of the fuel channels in CANDU reactors. During assembly and operation, these spacers may move away from their design locations and this can have adverse effects on the service-life of the unit. The development of means for fuel-channel Spacer Location and Repositioning (SLAR) is therefore highly important.

The garter springs are located with the use of classical eddy current probes.

A novel electrical device, based on the principle of the linear induction motor, has been developed for moving garter springs to desired locations on the fuel channels of reactors that are commissioned but not operating. This is the key component of the SLAR system; it provides the only way to reposition the garter springs under the stringent SLAR conditions.

The latest prototype operates at low power levels (208 V, 100 A, 60 Hz) in a wet channel with the fuel removed. A set of two of the devices has been built and incorporated into SLAR tooling for field use. The SLAR technology may be useful in CANDU reactors throughout the world.

A fully automated ultrasonic device which permits very rapid inspection of a limited part of the tube has been developed as part of the SLAR system. This detects the presence of hydride blisters at pressure-tube - calandria-tube contact zones.

Remote Inspection and Gauging of Pressure Tubes

Development of the fuel Channel Inspection and Gauging Apparatus for Reactors (CIGAR) has been completed. The apparatus measures the diameter and wall thickness of each tube at many locations, plots the sag profile of the tube, locates the garter-spring spacers and inspects the tube ultrasonically for flaws.

The CIGAR system provides Ontario Hydro with a number of new and significant inspection capabilities. Central Nuclear Services used the device to inspect 20 pressure tubes in an operating reactor at Pickering NGS during a 10-day period. The technology was also applied during an inspection of Pickering NGS Unit 8 pressure tubes after it was discovered that fretting by dummy fuel bundles had marked the inside surface. Development and application of methods of mapping the damage showed that if subsurface defects developed, they could be detected and distinguished from the surface damage.

Large-Scale Fuel-Channel Replacement

The Large-Scale Fuel-Channel Replacement (LSFCR) program is now under way for CANDU Units 1 and 2 at Pickering NGS. As part of this program, the Research Division has developed a fast induction heating technique for separating fuel-channel pressure tubes from their rolled joints with end fittings. With use of this technique, one end-fitting is retained undamaged on each tube. Without it, both end-fittings would have to be destroyed. The technique therefore produces a significant cost saving for Ontario Hydro and could ultimately be of substantial benefit to other CANDU owners.

The need for staff participation in LSFCR makes reduction of radiation fields in primary-heat-transport systems highly important. The CANDECON process, developed for this purpose by AECL in cooperation with Ontario Hydro, was successfully performed on Units 1 and 2 at Pickering NGS in 1984. Work continues to improve understanding of corrosion that occurs under CANDECON conditions and to lessen its effects.

Corrosion of Steam Generator Tubes

A major threat to the integrity of nuclear steam generator tubes is localized corrosion under sludge piles that accumulate on tubesheets. Contaminants normally present at low levels in steam-generator feedwater were found to be present at high concentrations in sludge from Pickering NGS. Electrochemical methods and laboratory autoclave studies were used to determine the nature and extent of corrosion under the sludge at steam-generator temperatures and pressures.

Scaling behaviour and corrosion in actual steam-generator water are being studied in autoclaves at Bruce NGS. Specially constructed probes are being used to determine the effect of stress on the corrosion process.

Two treatments are under development for the removal of sludge from in-service steam generators: chemical cleaning for Bruce NGS and high-pressure water jetting for Pickering NGS. This year a specific solvent composition for chemical cleaning was recommended. Studies continued of the effectiveness of water-jetting in lancing the sludge deposits with minimal damage to the tubes.

Factors affecting the deposition of magnetite particles and other materials on steam-generator surfaces are being studied. A model boiler test loop is being used to evaluate alternative pH and oxygen control agents that will minimize corrosion in condensate and feedwater systems and thereby reduce the ingress of corrosion products to the steam generators.

Corrosion of Heat Exchanger Tubes

A rig for corrosion testing of heat-exchanger-tubing alloys has been built at Pickering NGS to gain a fundamental understanding of the initiation and propagation of localized corrosion of tubes by Lake Ontario water. Immersion and electrochemical tests have identified alternative tubing alloys that have greater resistance to pitting in lake water than materials now in use.

Heavy Water Purification

Programs to improve technology for purification of heavy water in the primary-heat-transport and moderator systems of CANDU reactors are continuing. Detailed procedures for quality-assurance tests of resins used in the purification circuits of these systems have been developed and made available to help manufacturers to supply resins of appropriate quality.

Leak-Before-Break Characteristics of Materials

In cooperation with the ASTM, the Research Division has developed standard methods for measuring the ductile-fracture properties of steels. The measurements are being used to produce a data base of ductile-fracture properties in steels for piping in the Darlington NGS Primary-Heat-Transport (PHT) system.

In concurrent work, new concepts in elastic-plastic fracture mechanics have been applied in numerical simulation of the non-linear mechanical response of PHT system components to service loads. This will be used in conjunction with the material data base to assess the severity of cracks in PHT piping that are postulated for design purposes.

These projects are part of a joint leak-before-break program of the Research, Design and Development and Nuclear Studies and Safety Divisions to demonstrate the structural integrity of the Darlington NGS PHT system without modification to include pipewhip restraints.

Testing of Nuclear Process Equipment

Tests were completed on a Darlington NGS primary-heat-transport pump-motor set to determine the behaviour of the machine under two-phase, steam – water flow conditions that simulated a small-break Loss-Of-Coolant Accident (LOCA). The results confirmed the ability of the machine to tolerate rough operation without damage during LOCA conditions, and provided data on pressure pulsations for use in analysis of plant piping integrity.

A primary-heat-transport pump-motor for Darlington NGS is being disassembled for inspection after performance and endurance testing in the Nuclear Process Components Test Facility.

A modified version of a large isolation valve for the Bruce NGS emergency coolant injection system was also tested. Operation of the valve through many cycles over the full range of expected operating conditions showed the need for further improvements and retesting.

Work on the testing of nuclear station equipment was broadened to include qualification of electrical instrumentation and control components under the harsh conditions that could result from a postulated break in heat-transport primary circuits or steam lines. The environmental chamber now in use for tests on such components as cables, terminal boxes, switches and solenoid valves is being upgraded to handle larger components over a wider range of test conditions.

Refilling and Rewetting of Hot Horizontal Tubes

A need exists for a better understanding of the effects of refilling and rewetting hot horizontal tubes like those that might be found in a CANDU reactor under LOCA conditions. This has prompted a study that uses an experimental facility consisting of a horizontal, directly heated Zircoloy-2 tube, a water-injection system, and instruments for measuring void fractions, pressures and wall temperatures. Subcooled water is injected into the tube which has been heated uniformly to a desired initial temperature in the range from 300° to 600°C. Thermodynamic parameters are logged during each quench until steady state conditions are obtained.

The data obtained in this way have been used by AECL to verify the heat transfer part of the advanced thermodynamic code, ATHENA. Detailed wall-temperature measurements permit better estimation of inner-surface temperatures and heat-flux during the quench transient. The resulting heat-flux versus inner-surface temperature curve, termed the quench curve, may have significant effect in LOCA analysis.

Thermal Gradients and Tension Stiffening in Reinforced Concrete

A joint study by Civil Design and Civil Research of thermal gradient effects in reinforced concrete structures is providing data needed to improve current analytical techniques and to address questions related to the design, performance and safety of Ontario Hydro's nuclear containment structures.

Specifically, the thermal gradients encountered in LOCA conditions are simulated.

Test data from the first thermal-gradient model indicated that current analytical procedures give fairly good predictions of the response of members to thermal gradient loading, but tend to over-estimate the stiffness of cracked members and make inadequate provision

Workmen are finishing the installation of post-tensioning ducts and reinforcing bars of the vacuum building at Darlington NGS. Thermocouples and strain gauges were attached to the bars prior to concrete placement to permit research engineers to measure responses under test and operation conditions.

for concrete creep. Testing with a second thermal gradient model began in November 1985.

A research program has been undertaken to investigate tension-stiffening mechanisms, which significantly affect the response of reinforced-concrete structures to service loads. Three large-scale beam specimens have been built and tested with the beams in axial tension.

The program will support analysis of the performance of Ontario Hydro's nuclear containment structures under postulated LOCA conditions. The containments have been designed not to approach yield conditions even in such an extreme situation. The availability of a rational constitutive model for tension-stiffening mechanisms would permit analysis to determine the effective stiffness of the loaded members, the magnitude of the forces induced, and the crack patterns and subsequent redistribution of forces.

Decontamination of Spent-Fuel Storage Baskets

The decontamination of obsolete stainless-steel spent-fuel storage baskets from the irradiated fuel bay of Pickering NGS 'A' may lead to considerable savings in storage costs if the baskets can be decontaminated to a point where they can be disposed of as metal scrap. The search for a suitable chemical decontamination method has led to specification of a process based on a dilute aqueous solution of nitric and hydrofluoric acids. Application of this reagent to basket surfaces in laboratory trials yielded satisfactory results.

Recovery of Carbon-14 from Moderator Cover Gas

Most of the carbon-14 present in the moderator cover gas of CANDU reactors is released to the atmosphere in low concentrations during purging of the cover gas and other maintenance activities. With AECL's approval, a prototype scrubber for removal of carbon-14 from gas streams by adsorption on solid calcium hydroxide has now been designed for demonstration in 1986. The concept has been approved by the Atomic Energy Control Board and could be retrofitted to any CANDU reactor operating in Canada or abroad.

In related studies, a prototype cryogenic still has been completed to demonstrate the concentration of carbon-14 extracted from moderator cover gases and spent ion-exchange resins. If carbon-14 is enriched to a concentration above 90 per cent, a troublesome, long-lived nuclear waste becomes a valuable commercial byproduct.

The Cryogenic Chamber at the Tritium Removal Facility of Darlington NGS is undergoing its final inspection before it is sealed. Hydrogen gas is separated into its protium, deuterium, and tritium components by distillation at 20 K.

Flammability and Integrity of Station Control Cables

A fire test developed by Ontario Hydro has been adopted by CSA and in the National Building Code as the standard for evaluation of the flammability of grouped electrical and communications cables used in the control systems of nuclear generating stations. Cable-fire barriers have also been developed to minimize the migration of smoke and corrosive and toxic gas byproducts into station computer rooms and other sensitive areas during a fire.

Examination and tests of cable samples from Pickering NGS 'A' have shown negligible degradation of the cables after 15 years of service. Laboratory aging of the samples revealed that the cables would still be functional after a further 20 years of service.

Detection of Leaks in Nuclear Containment Structures

To retain their operating licences, proprietors of nuclear plants must achieve high standards of air tightness in reactor buildings and other containment structures. At present, leak detection solutions are the only effective means of locating air leaks in these structures. In research funded by COG, new tools based on ultrasonics and use of SF_6 as a tracer gas are being developed to achieve remote as well as quantitative detection of leakage.

Tritium Technology

Design and engineering of the Tritium Immobilization System (TIS) has been completed for the storage of pure tritium gas on a metal 'sponge'. The TIS will be part of the tritium removal facility being installed at Darlington NGS and is expected to find commercial application in other tritium handling processes.

A model of hydrogen permeation and recycling in Tokamak devices has been

developed and experimentally verified. Applications based on the property of asymmetric permeation in composite materials have been identified. These include tritium pumping and passive fuel purification. A prototype tritium pump, with no moving parts, has been designed and is being fabricated. Experiments conducted in Germany have verified the pump concepts. The concept of asymmetric permeation for experimental fusion devices has significant potential for commercial exploitation.

A compact, versatile gas chromatographic system has been developed for separating tritium and deuterium species from the purified exhaust gas streams of experimental fusion reactors. The system is intended to feed the separated species back into the fuel stream of the reactor. A prototype of the system has been completed which processes 1.7 litres of exhaust gases per hour, a capacity that suits the fuel-system recycling requirements of many present-generation experimental fusion reactors.

Sorption rates of tritium gas and tritiated water into four protective coatings and desorption rates from them were measured. While desorption of tritium gas is extremely fast, retention of tritiated water by the coatings is significant. This may have a major influence on decontamination procedures adopted for tritium removal and storage facilities. Epoxy mixes with a high pigment-to-binder ratio appear to be the best coatings for concrete used in tritium handling facilities.

THERMAL

Corrosion Problems in Thermal Plants

Laboratory testing has shown that failures of brass tubing in low-pressure feedwater heaters at Nanticoke TGS were initiated by a flow-assisted electrochemical corrosion process accelerated by the effects of elevated temperatures and high levels of dissolved oxygen, carbon dioxide and ammonia in the feedwater. Since the replacement of morpholine by ammonia for feedwater pH control in all units at Nanticoke TGS, tube corrosion has been significantly reduced.

Chemical treatments have been developed to reduce exfoliation of oxide scale from steam-exposed surfaces in superheaters and reheaters. Uncontrolled release of exfoliated scale can lead to serious mechanical damage to turbine equipment. The results of laboratory tests have shown that when tubes are treated with borate solutions the growth rate of steamside scale is slowed, scale adhesion increases and exfoliation decreases. In-situ evaluation of treated tubes will be continued for three years at Lambton TGS to assist with further development of measures for exfoliation control.

Corrosion-Fatigue in Carbon-Steel and Zirconium-Alloy Tubing

Corrosion-fatigue cracking in the carbon-steel tubing of fossil-fired boilers is being investigated in a project funded as part of an EPRI program. Various relevant boiler-water-chemistry conditions will be controlled inside tube samples and their effects monitored while the tubes are subjected to cyclic mechanical loads. A second facility is being set up to study the corrosion-fatigue susceptibility of carbon-steel and Zr-2.5wt%Nb tubing in CANDU units.

Life of Tubular Components Under Creep Conditions

Tubular components of various sizes and wall thicknesses, both with and without weldments, are being tested under isothermal and cyclic conditions over a range of internal pressures and tensile end loads. Factors affecting crack initiation and growth are being examined with a view to developing a quantitative relationship for life prediction.

Cleaning of Coal by Oil Agglomeration

In work funded by EPRI, the effectiveness and economics of spherical oil agglomeration were evaluated for the cleaning of coal to very low impurity levels. This process achieves high rates of recovery of coal fines from the cleaning-plant refuse stream. Bench and pilot-scale experiments have identified the optimum process conditions required for the production of clean-burning coal.

HYDRAULIC

Repair of Turbine Cavitation Damage

Erosion of turbine runners by cavitation is of major concern to operators of hydraulic generating facilities. Periodic repair of the damage involves gouging and grinding to remove unsound metal, then arc welding and final grinding to restore the original surface profile. This work is often done in-situ where access is difficult and working conditions are hazardous.

Ontario Hydro Research and IREQ are now engaged in a CEA-supported program to develop robotic methods and equipment for cavitation repairs. IREQ is optimizing equipment and controls for use with compact robots in the gouging operation and Ontario Hydro Research is adapting recently developed technology in surface mapping and automated welding for use in the repair process. When completed, the process will include robotic profile grinding as well.

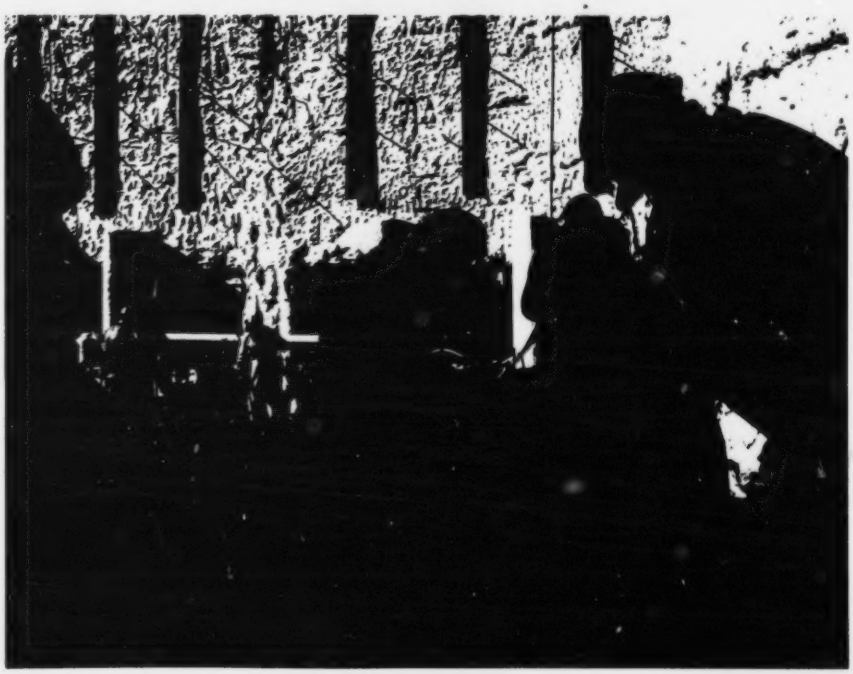
Performance of Concrete Hydraulic Structures

Fourteen concrete dams were visited to collect information on their condition after long periods of service in saturated conditions. The findings are being correlated with past records of accelerated laboratory tests and outdoor exposure tests of concrete specimens of various mix designs. The work is expected to result in improved test procedures for predicting the long-term performance of concreting materials for use in new structures and for repair of existing ones.

Monitoring Concrete and Rock Structures

Inverse and normal pendulums and wire extensometers are being installed for monitoring the long-term performance of dams at Abitibi Canyon, Little Long, Harmon and Kipling Generating Stations. Techniques for fabricating and installing the devices and interpreting the

The casing for a sliding micrometer is being installed to monitor the minute movement of a rock cliff above a generating station as part of a program to protect the station's structure and equipment from falling debris.



measurements were provided by Hydro-Quebec and a Swiss utility.

Monitoring of in-situ deformation in rock cliffs along the Niagara River gorge was begun in cooperation with a Swiss firm. Deformation is measured along a horizontal borehole by a sliding micrometer to an accuracy of 3 μm per 1 m of observed length. An extremely sensitive tool, the sliding micrometer also identifies active joints in the cliffs. This system has the highest resolution of any of its type in Canada, and interest in its use has been shown by AECL and Hydro-Quebec. Further use of the system is planned for several Ontario Hydro dams.

Research Division staff conduct surveys and inspections as part of a program to maintain the integrity of many old concrete structures. Rehabilitation work is shown underway on the 87-year-old intake structure that supplies water to DeCew Falls GS on the Welland Canal.

OTHER STUDIES

Modelling of Large Synchronous Generators

In simulation studies to determine power-system operating limits, models of system components, such as generators, excitation systems and speed governing systems, must accurately represent the equipment used in the field. System components are therefore tested intensively to acquire data for modelling.

In 1985 the standstill frequency response method of testing two- and four-pole synchronous machines, a technique pioneered by Ontario Hydro, was made a trial-use standard of the IEEE. A CEA contract in which five large turbine generators at various locations across Canada were tested by this technique was completed.

A method to better approximate the steady-state operating conditions of a unit promises substantial economic benefits by allowing use of a little more of the generation that has been "locked-in" at Bruce NGS as a result of delays in transmission-line construction. Tests have been completed on two Bruce NGS units, and payback is expected in 1986.

Surge Protection of Generators

In a project funded by EPRI, the Research Division is making a detailed investigation of the surge environment at the terminals of large synchronous generators. The recent trend towards use of generator breakers has added a number of new mechanisms for possible switching transients. Models based on field tests are being developed for simulating unusual or potentially hazardous system conditions. The surge-withstand capabilities of generators are also being examined, as is the current practice of generator surge protection. The results of this project will affect the design of future generating stations and could lead to modification of current operating practices.

Large generators and motors are integral parts of the process of producing electricity. Non-contact transducers are used to measure shaft vibration and thrust-bearing oil-film thickness as part of a new computer-automated "Monitoring for Predictive Maintenance" system that is intended for use in planning maintenance of the hydraulic generators at the Sir Adam Beck - Niagara GS.

Power System Stability

Continuing delays in the construction of transmission lines, the commissioning of additional generation and the need to maintain export capability make improvement of power-system stability an increasingly critical requirement.

The latest in power system stabilizers, which work through the excitation system of the generator, are being commissioned at Bruce NGS as units are brought into service. Similar stabilizers are being supplied for the Darlington generators. Without these control systems, there would be substantially more 'locked-in' generation at the Bruce NGS and power export capability would be restricted.

Controls that enhance transient stability have been developed and applied to nuclear units at Bruce NGS and coal-fired units at Nanticoke TGS as a means to further improve system stability. These controls act through the excitation systems to maintain a higher than normal terminal voltage on the generator for about one second after a major system fault.

The State Electricity Commission of Western Australia (SECWA) has purchased four of Ontario Hydro's power system stabilizers. These are being installed on existing fossil-fired units and commissioned with the assistance of Research Division personnel. The use of these stabilizers on the SECWA system has the effect of making the stability of their system insensitive to variations in system load characteristics.

Computer-Managed Monitoring of Rotating Machinery

The Research Division has developed a computer-managed system for monitoring vibration of rotating machinery to detect deterioration at an early stage and identify probable causes. The system will use a total of 508 sensors on 124 pumpsets in four CANDU nuclear units. It will make base-line comparisons, generate trend plots and perform pumpset condition analyses. Diagnostic logic incorporated in a knowledge-based system will automate the decision-making process

that a vibration analyst would follow in evaluating a set of vibration signatures.

The system will reduce pumpset maintenance costs and improve plant availability at Darlington NGS, now under construction. With development of the necessary knowledge-base, it could be adapted to monitor other rotating machinery.

Improved Facilities for Seismic Testing of Station Equipment

Two tri-axial shakers are now available for the seismic qualification of small- and medium-size nuclear plant equipment. Two new environmental chambers are being commissioned for accelerated aging of test specimens to accommodate a shift in emphasis to seismic testing of artificially aged rather than new equipment.

Following quidelines set by the Sandia National Laboratories in the United States, the performance of new and aged station batteries was evaluated before, during and after seismic testing. Conditions were representative of the strongest earthquakes anticipated for the sites of nuclear installations. From the tests an extremely durable battery cell has been identified which is little degraded by natural or accelerated aging and seismic stresses.

Improved Soniscope

With support from the CEA and Hydro-Quebec, Ontario Hydro is developing a new Soniscope based on modern electronics technology for use in the non-destructive detection and location of cracks in hydro-electric dams and other mass-concrete structures. The original device was first developed by the Research Division in about 1949 and has since been in use commercially with little or no change in its design.

This pressure switch is one of many devices tested for seismic qualification on the new small tri-axial shaker. The testing is part of an ongoing process to determine the ability of the many components of Hydro's nuclear stations to withstand seismic shock.

Failure Analysis

Conventional techniques for analysis of failure modes in power-system components are usually destructive as they require removal of representative samples for examination in the laboratory. Many components could be saved if there were effective techniques for in-situ, non-destructive metallurgical evaluation. Therefore a major effort was made with support from the CEA, to develop and refine such techniques.

Preparation of surfaces for microscopic examination has been made more efficient by improvements in abrasive and electrolytic polishing. Replication of surfaces also has an important role in metallurgical field work as the shape of components often makes in-situ microscopic examination impossible. Improvements in the convenience of replication and in its definition of metallurgical structure have been effected. These techniques have been used extensively in assessing the integrity of power plant components, such as the rotating parts of steam turbines.

New Applications of Holography

The aim of this work is to develop holographic procedures for in-situ analysis of flaws and vibration in tubes, piping and other station components. Holographic apparatus was used to observe vibration patterns in sections of pressure tubes and turbine blades. Images of standing waves were obtained, and in the case of pressure tubes, movement of garter springs to nodes was displayed. The work on turbine blades was done for a Canadian manufacturer and clearly showed blade vibration patterns as a function of excitation frequency.

Transmission and distribution lines and transformer stations represent about one quarter of Ontario Hydro's capital investment. Facilities include about 27 000 circuit-km of transmission line and 100 000 km of distribution line, and associated transformer, switching and distribution stations.

Current transmission research programs are concerned with topics such as the uprating of existing lines and stations, while distribution research is focused on the development of techniques required for improved safety and reliability.

TRANSMISSION

Probability-Based Methods for Transmission-Line Design

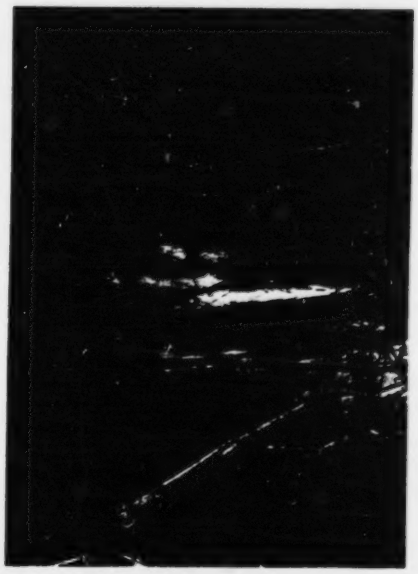
In 1982, EPRI formed a team of experts, including personnel from Ontario Hydro, to prepare a comprehensive guide for use of probabilistic methods in the design of transmission lines. The deterministic design approach now in general use has limited ability to assess structural reliability in quantitative terms. The probability-based method, on the other hand, represents the variability of loads on structures and strengths of components more realistically and offers a quantitative measure of reliability level. Its adoption will enable utilities to reduce capital costs and maintain or improve reliability levels. EPRI expects to issue the guide towards the end of 1986.

The Research Division has made a significant contribution in the area of loads on conductors caused by ice and wind-on-ice. This section of the guide deals with definition of various ice accretions, use of models in calculating ice build-up, estimation of extreme ice accumulations and calculation of wind loads on ice-covered conductors.

Ontario Hydro has also provided detailed information on test sites used for monitoring wind and ice loads on transmission lines in Canada, the USA and Europe.

Optimization of Transmission Line Design

A program to optimize the design of transmission lines is under development. This treats conductors in an abstract way, because a standard conductor that meets optimum requirements for given load-growth profile and economic forecasts may not exist at present. The optimization process minimizes the sum of capital costs, and the present values of energy and peak power losses over the lifetime of the line. This results in an optimum combination of conductor size, steel-to-aluminum ratio, bundle size, span length and type of support structure that meets given safety, reliability, environmental and political requirements.



Towers lying like broken giants on the Essa to Claireville 500-kV transmission line are a result of a tornado that ripped through southern Ontario in the spring of 1985. Storms with such force are very infrequent and are not normally provided for in transmission-line design.

Low-Loss ACSR Conductors

A model of ac resistance in steel-reinforced aluminum conductors (ACSR) recently developed by the Research Division is being used to design low-loss ACSR conductors. The ac loss of one conductor design has been reduced by 2.5% by a change in the lay-lengths of its three aluminum layers. This change is not expected to lead to a significant increase in the cost of producing the conductor. Other designs result in loss reductions of as much as 8%. However, these involve the use of different wire diameters in each aluminum layer which could increase costs.

Analysis and Improvement of the Thermal Environment of Power Cables

Several "user-friendly" desk-top-computer programs for thermal analysis of power cables have been developed and transferred to the R&D Division of CEA for distribution to all Canadian utilities and sale to American utilities and cable manufacturers. The programs will permit cable engineers to use desk-top computers in complete thermal analyses by either the classical Neher-McGrath/IEC method or modern finite element techniques.

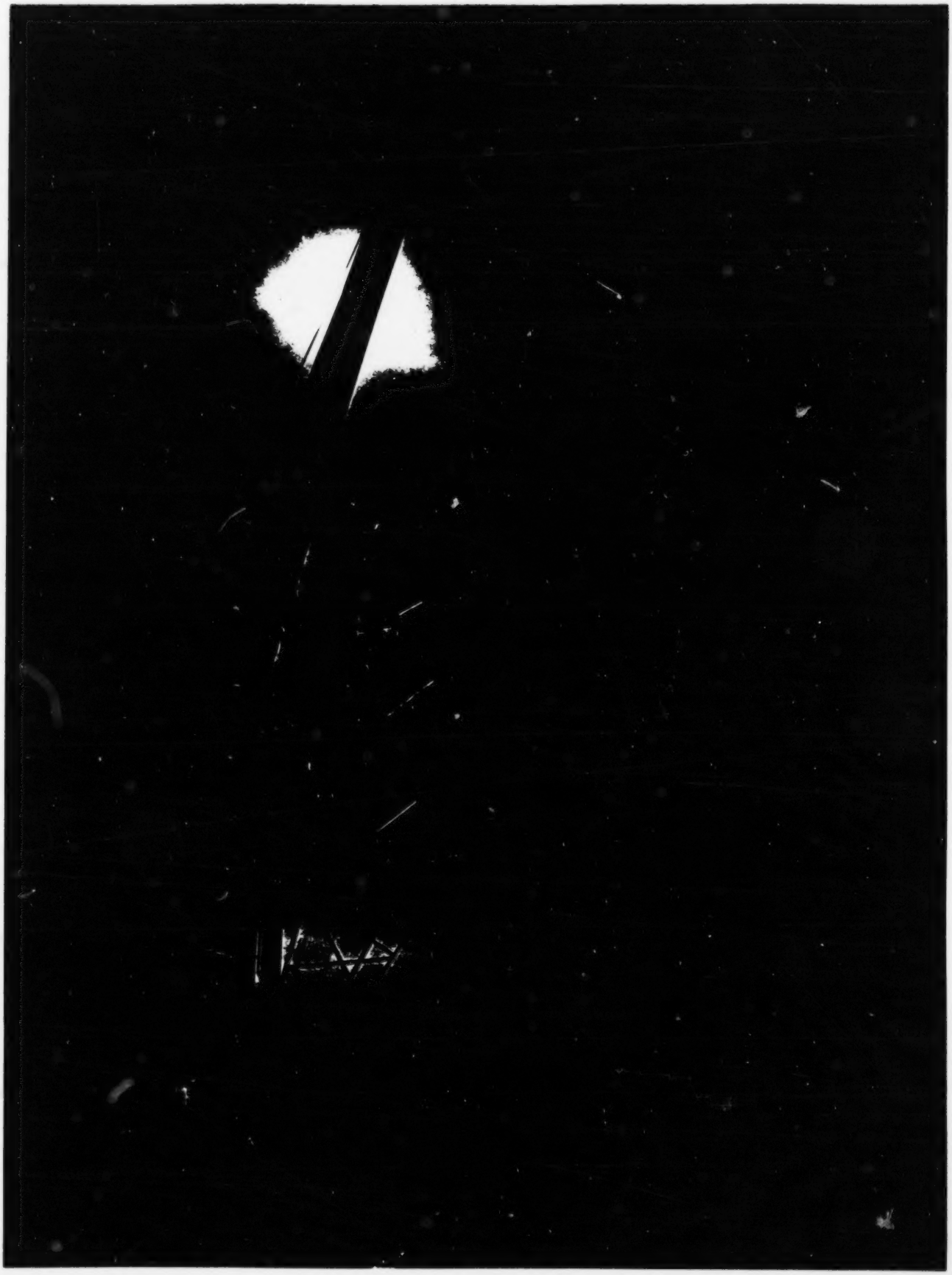
Re-radiation of Broadcast Signals by Transmission Lines

Guidelines that limit the effects of re-radiation by transmission structures on the broadcast patterns of nearby radio transmitters are an increasingly contentious issue in relations between electric power utilities and radio broadcasters. This trend is increasing demands by utilities for "user-friendly" computer programs developed by the Research Division which provide easy and accurate evaluation of the effects of proposed transmission lines on the broadcast patterns of nearby radio transmitters. The programs can also evaluate the effectiveness of various schemes to reduce re-radiation.

Power-System Harmonic Measurement

The power and telecommunication utilities are involved in a major effort to

Construction crews responded quickly after tornados destroyed transmission towers in southern Ontario. This photo, taken a week after the storm, shows a crew erecting a replacement tower with the aid of a mobile crane and fall protection equipment tested and evaluated in the Division's Mechanical Testing and Development Complex.



develop a comprehensive electrical coordination guide for utility engineers. As part of this, a Research Division project funded by the CEA is underway to develop a standard harmonic-measurement instrument that will provide convenient data for standards and procedures to improve control of power-system harmonic distribution. The project is scheduled for completion in 1986.

Metal-Oxide Surge Arresters for Transmission-System Protection

Metal-oxide arresters are becoming the dominant protective devices for major electrical equipment on transmission networks. However the electrical properties of the key protective components, the varistor elements, vary from one manufacturer to another. A number of studies have been undertaken by Research to support users in assessing and applying metal-oxide arresters. These include long-term thermal aging, x-raying of arresters to check internal structure, field testing, modelling, pulse testing, and development of arresters for application on underground cable systems. The Division is participating in the development of standards for metal-oxide surge arresters by committees of the CSA, the IEEE and the International Electrotechnical Commission.

Conductor-Vibration Control

Ontario Hydro and CEA-sponsored field trials of detuning pendulums and other devices for control of galloping on distribution lines and bundle-conductor transmission lines are now established at about 40 sites across Canada. Utilities are observing and filming conductor behaviour during ice storms.

The incorporation of detuning pendulums in the design of the Hanmer-Mississagi 230- and 500-kV lines is permitting upgrading of line reliability without redesign of structures or reduction of span lengths. Licenses for manufacture of devices applicable to single conductors have been granted to one Canadian and one Norwegian manufacturer.

Dampers for control of aeolian vibration of overhead transmission and distribution lines from a number of sources in Canada and elsewhere are being evaluated on Ontario Hydro's indoor test-span. A new technique is being used which determines the energy absorption throughout the range of frequencies encountered during normal operation.

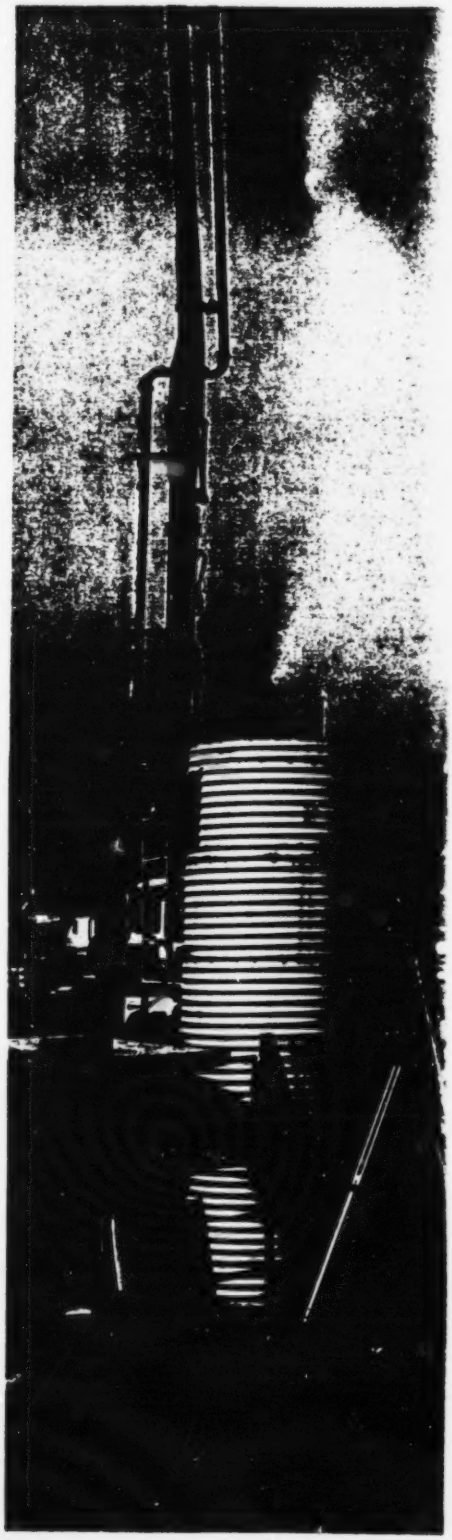
Spacer-dampers to control wake-induced vibration of four-conductor bundles are being evaluated in a field test on the Lennox-Newtonville 500-kV line. The vibration levels on each of the six phases, which are treated with different hardware, are being monitored by live-line recorders.

SF_6 Arcing Byproduct Analyzers

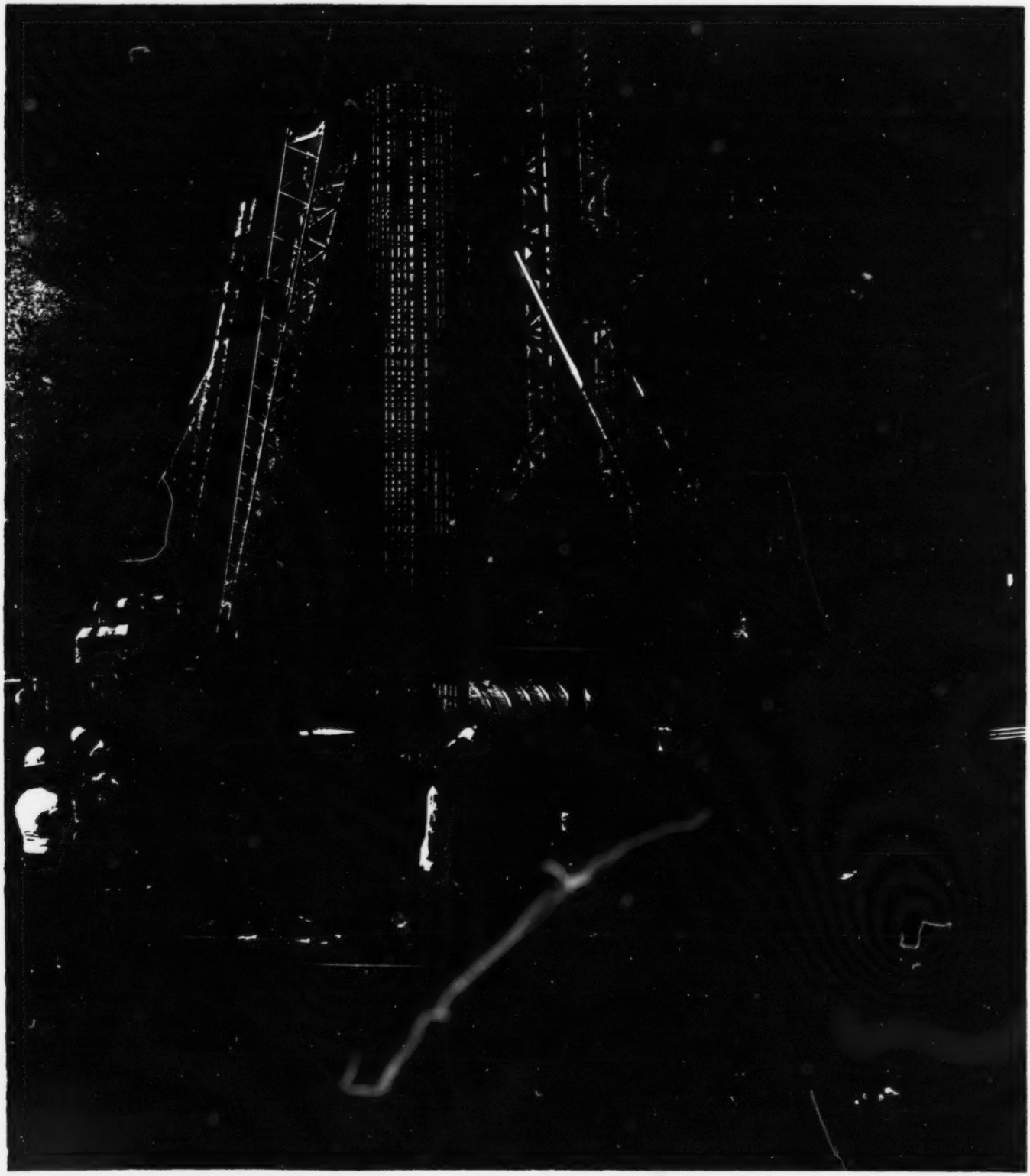
The Research Division has developed two low-cost analyzers of SF_6 arcing byproducts for use in gas-insulated substations. These are based on commonly available detector-tube technology and are very sensitive. They can be used by field staff without extensive training for rapid in-situ analyses, for diagnostic purposes and for fault location and partial-discharge detection . Testing of analyzers at substations after power arc faults provided excellent correlation with laboratory results.

In-Situ Testing of Soil

Devices for testing of soil in-situ along transmission-line routes offer considerable potential for reducing the time and labour involved with laboratory testing. Field tests which used a dilatometer, static cone, borehole shear device, Pencel probe, geophysical equipment, pressuremeters, and more conventional tools have been done at two soft-clay sites. Geotechnical Engineering is participating in the evaluation and is training staff to provide for future transmission line investigations on a production testing basis.



At the centre, a reinforcing cage is being lowered into an augered hole prior to the placing of concrete for a transmission-tower foundation in soft clay. The photograph also shows, at the right, the augering of another hole, and at the left, a finished foundation awaiting installation of equipment for an overturning-moment test.



The soft clay that underlies much of eastern Ontario loses strength when disturbed by construction and regains part of the loss by thixotropy over time. In cooperation with the National Research Council, drilled holes up to 3 m in diameter and 13 m deep are being load tested to determine parameters used for design of transmission tower foundations in this part of Ontario. Construction procedures are also being reviewed.

Anchor Grouting and Bearing-Pad Construction at Low Temperatures

In northern Ontario, transmission lines are often built in winter because the abundance of lakes, swamps and muskeg makes ground travel difficult in the warmer months. However, construction of small concrete footings and of anchors grouting in winter is expensive and time consuming. At present the rock surface is heated for up to 24 hours to provide a warm base for grouting the anchor bolts and mixing and placing conventional grout or concrete. The footing is then covered and heated for the three days needed for curing.

Research was therefore undertaken to develop materials with properties that would mitigate these problems but still provide the necessary structural properties. The outcome was development of polymer materials which permit both anchor and base-plate grouting at temperatures as low as −25°C.

DISTRIBUTION

Distribution System Automation

The rapidly advancing technology of distribution-system automation involves load management, voltage control, remote switching, remote meter reading and other system-operation functions. Successful implementation of this technology requires an effective and economical technique for sending and receiving operational commands to and from remote devices.

Power-line carrier is an attractive medium for this purpose, but the technique must be made effective and reliable. A computer program, developed in a project sponsored jointly with CEA, can be used to analyze carrier-signal propagation and predict signal levels at any point on the distribution system. It will enable the utility engineer to optimize parameters such as carrier frequency, required signal injection levels, and points of injection without need for costly field trials.

The feasibility of using commercially available fibre-optic equipment for distribution system communication is also being investigated in a project supported by CEA.

Improvements in Line Insulation

The transfer of insulator technology developed by the Research Division to local industry is leading to increasing use of lightweight, state-of-the-art polymer insulators for overhead distribution circuits. Approximately 35,000 polymer insulators are now installed yearly on Ontario Hydro distribution lines.

Ontario Hydro has played a major part in the development of the first industry guide for application of polymer insulators to overhead transmission and distribution circuits. This was published by the standards board of the IEEE in July 1985, as ANSI/IEEE Standard 987.

Research Division collaboration with

Readings are taken from the display of a pressure meter connected to probes installed at various depths in the soil to determine moduli of elasticity for use in the design of transmission-tower foundations.

the University of Windsor on polymer materials for electrical insulation applications outdoors has contributed to better understanding of insulator material performance and to development of improved materials. The program receives support from the National Sciences and Engineering Research Council, the Electrical Insulation Society, and industry.

Explosive Effects in Surge Arrester Failures

When a distribution surge arrester fails, the porcelain body sometimes bursts. A novel device for disconnecting the arrester ground-lead and eliminating this dangerous possibility has been developed in a program sponsored jointly by Ontario Hydro and the CEA.

The device can be attached to new arresters by the manufacturers and to existing arresters by the utilities. It works by rapidly cutting off the flow of fault current in a failed arrester in a way similar to the operation of a current-limiting fuse. However, the arrester, unlike the fuse, is not affected by lightning surges and normal power-follow currents. Negotiations are underway with a large surge arrester manufacturer for production of the device in Canada.

Strength Testing of Wood Poles

A test program of about five years duration has been initiated to establish a data base for the strengths of wood poles on Ontario Hydro distribution systems. An automated test facility has been designed, but at present only a temporary facility has been placed in service to permit testing for another utility of 34 poles which the company suspected of being under-strength. The results of these tests indicate that wood poles now going into service may be much weaker than had been expected. Further tests in cooperation with the other utility and their pole-treating company are planned.

The new facility, which is expected to be ready for use in the spring of 1986, will normally be capable of testing poles up to 26 metres long. Bending moments of up to about 1700 kN·m can be applied with the load rate and direction automatically controlled to comply with the requirements of ASTM Specification D 1036.

Vegetation Control Along Overhead Lines

The periods of trimming cycles for trees under distribution lines depend on the rates and patterns of growth of various species and range from one to eight years. Extensions of some or all of these cycle times would substantially reduce tree-trimming costs. Experiments are continuing to determine the allelopathic effects of some cover crops and their potential usefulness in inhibiting the invasion of rights of way by undesirable woody species. The inhibition of seed germination by aqueous extracts prepared from these cover crops was found to be less than universal; one seed species is resistant and others may be. Extracts from older plants were found to be generally more inhibitory than those from younger plants. Improved knowledge of the competitive and allelopathic effects of some cover crops may lead to useful modification of the vegetation management program.

Determining Submarine Cable Ampacity

The increase in use of electric heating and the general growth of customer loads have increased the need for precise knowledge of the allowable ampacity of the submarine cables that are used to supply island customers on Ontario Hydro's rural distribution system. This cable is of unique and economical design; it has no concentric neutral and thus any return current flows via the ground, the water or the steel-wire armour that protects it.

At the places where the cables pass from water to soil and from soil to air (up a riser-pole) ampacity is of particular concern, for at these places there is an increase of current in the armour wires and a reduction of cooling. Tests have been made in the field to determine the amount of current typically flowing in the armour wires. In the laboratory, tests have been made to determine the temperature rises that occur in various sizes of submarine cables with various currents flowing in the phase and armour wires. The results are being used to verify a computer program used to calculate cable ampacity. The work will allow loading of submarine cables to maximum capabilities with good assurance that they will not be overstressed and thus prone to failure.

Evaluation of Toxic-Gas Detectors

Portable detectors are used to test for the presence and concentration of toxic gases in confined spaces, such as manholes, where utility staff must often work. The Research Division has evaluated nineteen detectors from a number of manufacturers in a program supported by Ontario Hydro, the Association of Municipal Electrical Utilities (Ontario) and the CEA. The program has established the effects of instrument-related factors (design, calibration, operating instructions, servicing and handling) and of workplace conditions (temperature, humidity and interfering gases) on the reliability of measurements provided by the instruments in various applications. This information will be useful in choosing the most suitable instrument for a specific application.

Distribution Instrumentation

A microprocessor-based Maximum Demand Indicator, developed for use in revenue-metering applications, accepts pulses from kW·h and kVA·h meters, and displays the maximum kW and kVA demands and the present power factor. The federal government has approved use of the demand indicator in billing applications and a licence has been awarded to an Ontario company to produce the device and sell it to other utilities.

The Ampere-Cycle Totalizer, recently developed by the Research Division, provides information for use in decisions on the timing of breaker maintenance. It monitors the magnitude and duration of the arcing current to which breaker contacts are subjected, and stores and displays a cumulative total of these ampere-cycles for the life of the breaker. The peak fault current interrupted by the breaker is also measured and stored.

Utilization

Because of its high efficiency and relatively low cost, electricity is an attractive alternative to oil and gas as an energy source for many industrial applications. It can also provide other benefits, such as reduced waste, clean working environments and improved productivity and quality control.

INDUSTRIAL

In a continuing search for novel and advantageous applications of electricity in industry, the Research Division investigates new electrotechnologies as they develop. Those of special interest at present include applications of heat pumps, plasma arcs, radiant energy and electromagnetic devices, and new processes in the electrochemical and ceramics industries.

Radiant-Energy Technologies

Radiant energy technologies include applications of microwave, infrared, ultraviolet, laser and electron beam devices. These electrically based technologies offer significant benefits to industrial users through increased productivity, improved product quality and more efficient use of energy and space.

Two versatile test facilities which demonstrate the application of microwave and infrared technologies in various manufacturing processes were commissioned. Preliminary assessments have been made of the benefits of microwave heating in terms of increased product throughput and reduced energy consumption. For example, assistance was given to a manufacture of rubber products. Laboratory tests demonstrated that the heating of rubber using microwave radiation was more energy efficient than by using conventional sources.

Applications of microwave, radio-frequency and infrared devices in manufacturing were investigated jointly by CEA and Ontario Hydro. This study, which is of special interest to utilities, examines the application of these electroheat devices worldwide and indicates possible opportunities for their use in Canada.

The use of microwave technology can dramatically enhance industrial productivity through increased production rates, higher yields and improved product quality. Applications of microwave heating range from the preheating of rubber to drying of ceramic products. A test on a wood product is shown.

Heat-Pump Drying

The heat pump is a machine that can produce low-cost process heat by recovering and upgrading heat previously lost during manufacturing processes. Thus, this technology can be used to dry products using a fraction of the energy required otherwise. For example, heat-pump dehumidification is currently being used to dry hardwoods for the manufacture of furniture. The use of heat-pump dehumidification to lower the cost of producing other wood products, thread, food and textiles is also being explored. Preliminary investigation, made in cooperation with a thread manufacturer, has shown that conversion of the drying process from resistance heating to heat-pump dehumidification can result in a 50 per cent reduction of the electrical energy used. Through studies like this, conducted in cooperation with manufacturers and equipment suppliers, Ontario Hydro can help Ontario industry benefit from the use of this efficient electrotechnology.

Electrochemical Technologies

A study, jointly funded by CEA and Ontario Hydro, of the impact of new electrochemical technologies and processes on the demand for electrical energy was completed. Some of the areas showing possible commercial opportunities included primary metal recovery, inorganic chemical production, pollution control and electro-organic synthesis. The roles of industry, educational institutions, government and electrical utilities in promoting this opportunity in Canada were defined.

In some industrial processes, membrane separation technology is used to separate one substance from another. In this technology thin films of certain organic polymers form barriers that permit molecules of one kind to pass but exclude all others. A report was issued which reviewed the current applications of membrane processes. These offer the potential of both saving energy and improving productivity, as compared to

Wood is one of many products being tested in a heat pump dehumidification kiln as part of a program to demonstrate this efficient drying method. Textiles, grains, malts and fruit are some of the other products being considered for the heat-pump dehumidification process.

conventional techniques such as evaporation or distillation. Intended as a primer for utility personnel, the report summarizes the application opportunities and development needs in this relatively new technology.

Electromagnetics

Research is being conducted to harness electromagnetic fields to produce large forces and high temperatures in a well controlled manner. The Electromagnetics Laboratory was substantially upgraded during the year to facilitate both research work and the demonstration of this advanced technology to Ontario industry.

Problems in the application of induction heating for heat treating and metal processing were investigated. Technical assistance was provided to several manufacturers on development of improved methods for annealing of special cables, hardening of automotive parts and melting of disposable metal beverage cans.

Thermal Plasma Technology

The Thermal Plasma Laboratory, which features an 80-kW plasma torch equipped with a powder injection system, has been utilized in several research programs. These have included studies of the processing of ceramic powders, metallurgical processing of compounds to produce ceramic magnets, recovery of magnesium and fluorine from uranium oxide process waste-streams, and the production of metallurgical reducing gases from coal-steam mixtures. All of these programs were conducted in collaboration with external agencies. A second plasma laboratory under construction adjacent to Lakeview TGS will use a 250-kW plasma torch in a

Advanced Ceramics

Advanced ceramics are characterized by superior strength and hardness and have desirable chemical properties such as resistance to corrosion. High-temperature strength and wear resistance are other attractive features. The Research Division has taken steps to help industry develop efficient processes for the production of ceramic materials and components. Much of the present interest in these materials is related to their possible use in diesel and gasoline engines.

The Thermal Plasma Laboratory and the Microwave Facility have been used in several ceramic material processing projects with Ontario manufacturers. An induction plasma system is being added to expand the capabilities of the plasma laboratory.

RESIDENTIAL

Interest in comfort and safety and efficient energy use in the home has grown considerably in recent years. The Division's efforts have been directed at efficient energy management and have included development of a cold-climate

heat pump, and studies of the thermal upgrading of homes and the recovery of waste heat.

Cold-Climate Heat Pumps

Laboratory testing of a new air-source heat pump has shown that its low-temperature efficiency is the best in the world. This residential heat pump, with improved performance in Canadian climatic conditions, was developed by the Research Division in a project supported by CEA.

Following release of the Research Division's design report to the heating, ventilating and air-conditioning industry, CEA authorized a Canadian manufacturer to develop a commercial design and build seven prototypes units. These were shipped to utilities in both Canada and the U.S.A. for field testing. Successful performance of the electronically controlled expansion valve and other features could influence the design of future generations of heat pumps and result in energy savings worth $18 M in Ontario over the next ten years.

Thermal Upgrading of Houses

Sixteen houses equipped with dual-energy heating systems were thermally upgraded and their energy consumption monitored for a year before and a year after the retrofit to determine any changes in energy consumption and demand. On average, energy savings amounted to six per cent while peak power demand was reduced by thirteen per cent. Although the saving to customers was much smaller than predicted, thermal upgrading of homes is still a strategic conservation measure.

Patterns of Hot-Water Use

Domestic water heating represents a major use of energy in the average home. Over the past decade, the structure and life-style of the family have gone through changes that have altered the household's hot-water consumption.

Data compiled over the past four years from fifty-eight homes show that knowledge of the total daily and peak hourly hot water use is important in the accurate sizing of water-heating systems. New design and evaluation criteria based on the hot-water consumption patterns observed in this study will be of assistance in the design of water heating systems.

Conservation

Research activities were directed towards the testing and evaluation of a new generation of heat-pump-based devices that provide mechanical ventilation and humidity control to improve indoor air quality. The devices recover a large part of the thermal energy in the exhaust air for use in space and water heating.

Waste-water heat recovery systems were also assessed. These systems are designed to transfer heat from warm residential waste water, such as that from clothes washing, dishwashing and showers, to fresh, potable water, which can be stored in a domestic hot water storage tank.

The attractiveness of these relatively new technologies stems from their high efficiencies. Consequently there is the potential for significantly lowering energy consumption in both new and retrofit applications.

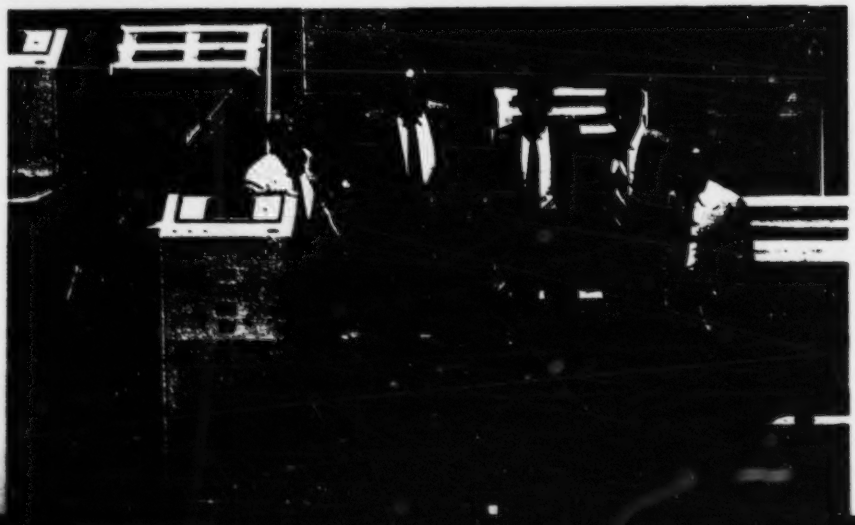
Residential Service Entrance and Wiring

As part of its mandate, the Research Division has looked at ways to improve the performance and reliability of customer-owned electrical equipment.

A prototype "smart" fuse has been designed that will allow the homeowner to add the comfort of supplementary baseboard heating to any room in the house by merely plugging the heaters into existing wall receptacles. Any overload on the circuit is detected by an electronic mini-breaker device that replaces the standard fuse in the panelboard. It then transmits a signal to turn off or reduce the output of the baseboard heater to remove the overload condition. Once the device responsible for the overload is removed from the heater's circuit, the heater is allowed to resume normal operation. When fully developed, the "smart" fuse will be ideally suited for the retrofit market.

A study was conducted for CEA to develop methods of minimizing fires arising from residential service entrance panelboard failures. After testing of ceramic fibreboards and various types of sprays, foams and pastes applied to panelboards, a recommendation was made that a minimum standard for panelboard backing materials should be incorporated into regulatory standards.

Successful research and development requires the transfer of ideas from the laboratory to the marketplace. Shown here with prototype units of the CEA northern climate heat pump that are now undergoing field trials in Canada and the United States are representatives of the three key organizations that took this development from conception to reality. From left to right are: Dave Robertson and Grant Blackmore, from KeepRite Inc; Fred Kee and Ed Ezer, Directors of Research from Ontario Hydro and CEA respectively; and Dave Young and Anton Baljet, from Ontario Hydro's Electrical Research Department.



Tests to determine the merits of the tin-plating of fuse contact surfaces indicate a three-to-one reliability improvement for heavily loaded fuses that are tin-plated. The tin plate was found to give a better connection and to reduce the incidence of nuisance fuse-blowing.

Heating-Load Calculations

Calculations of residential heating loads using measurements from previous dual-energy and thermal envelope upgrading experiments indicate that, in general, furnaces have roughly twice the capacity needed. This results in increased capital cost and a lower comfort level for the homeowner. A significant contribution was made to a new CSA standard to be used for sizing furnaces supplied by any type of energy.

COMMERCIAL

Throughout the year, various ways of improving the efficiency of energy use in commercial establishments were investigated. Research was carried out in such diverse areas as the use of warm water discharged from generating stations for freshwater-prawn farming and the suitability of heat-pump water heaters for commercial applications.

Thermal Aquaculture

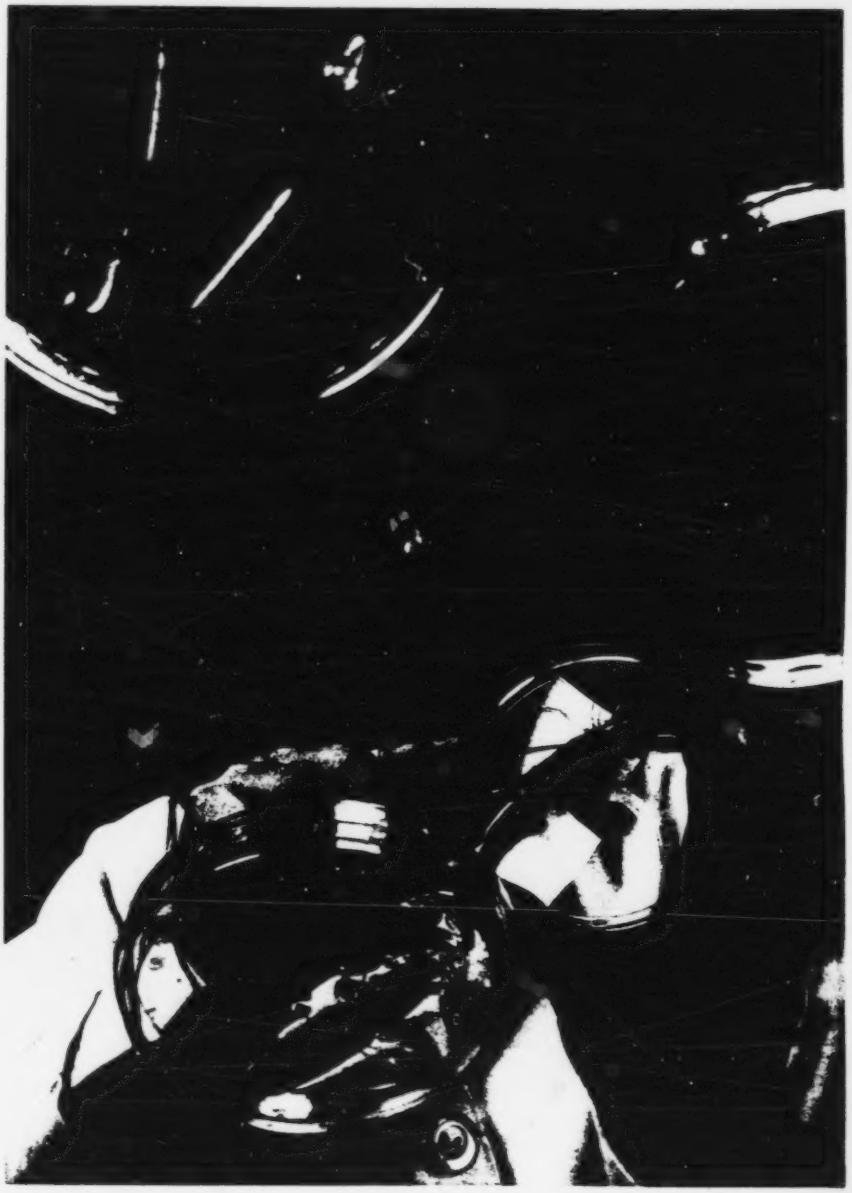
Work continues on determining the feasibility of growing Malaysian prawns in warm-water discharges from stations. The investigation, which initially centred on the selection of the optimum diet for the prawns, is now at the stage where the amount of food required for optimum growth of the animals is being studied. A preliminary "growout" trial of these animals to marketable size produced yields comparable to those reported for commercial Hawaiian ponds.

Commercial Heat-Pump Water Heaters

With increasing energy costs and general public awareness of the benefits of energy conservation, heat-pump water heaters have emerged as an attractive option for increasing the efficiency of electric water heating in commercial applications. Over 10 MW·h were saved during the year in a restaurant where a small heat-pump unit was installed to air condition the kitchen and to heat water for various applications.

Within the framework of a CEA project, a larger heat-pump water heater has been recently installed in this restaurant. This example may encourage other commercial hot-water users such as hotels, laundries, apartment buildings and public swimming pools to take advantage of the benefits offered by heat-pump water heaters.

Several prawn aquaculture studies that would make practical use of low-grade waste heat from nuclear stations were conducted throughout the year. Tests were conducted to determine the minimum daily food ration for optimum growth of the prawns.



Environmental Protection

The Research Division undertakes studies of the effects of power-system operation on the biosphere to support the Corporation in following guidelines and regulations set by environmental assessment and control agencies. Procedures, processes and equipment are developed as necessary for the control of emissions and effluents from generating stations and related installations, and for the safe handling, storage and disposal of waste materials. Other areas of study include diversion of fish from station water intakes and conversion of toxic substances to harmless products.

POLLUTION-RELATED STUDIES

Limestone Injection for Combustion-Gas Cleaning

A limestone injection system now under development for possible application to Ontario Hydro's coal-fired generating units could reduce sulphur-dioxide emissions by as much as 50 per cent. A prototype system has been installed at one of the 300-MW units at Lakeview TGS.

A research program in support of the project is providing information necessary to evaluate the applicability of the limestone-injection technology to Ontario Hydro units and to enhance the technology available for the clean use of coal. The program will both contribute to and supplement the full-scale prototype tests at Lakeview TGS. The program objectives are: to determine the operating conditions required to achieve optimum SO_2 capture and sorbent utilization; to evaluate the performance of electrostatic precipitators under optimum process conditions and to develop methods to improve their performance; and to assess the slagging and fouling potential in the furnace from increased ash loading.

The operation and performance of nineteen portable, direct-reading gas monitors were evaluated in a project co-funded by CEA, the AMEU and Ontario Hydro. These monitors are used to test the atmosphere of confined spaces both prior to entry of personnel and while work is in progress.

In the first phase of the program, thermogravimetric analysis was used to study the reactivity of six Ontario limestones and one limestone was recommended for pilot-plant tests. A bench-scale reactor which will allow more precise studies of the calcination and sulphation reactions of various adsorbents under controlled conditions has been designed and built. Models developed by the US Environmental Protection Agency and others have been evaluated and a suitable one has been obtained to study expected limestone behaviour in boilers.

The second part of the program is being conducted at Ontario Hydro's 640-MJ/h Combustion Research Facility. To meet the requirements of the program, the Facility has been upgraded to include a furnace quenching system, limestone and water injection systems, an isokinetic sampling system, and a coal grinding and pneumatic conveying system.

Modelling of Cloud Chemistry

In cloud-chemistry studies co-funded by CEA, schematic models were developed to examine the role played by stratus, cumulus and frontal clouds in redistribution of air pollutants and formation of atmospheric acids. Work on dynamic models with increased credibility is well underway.

Acid-Rain Studies

In a project co-funded by CEA, the first extensive field measurements of dry deposition - the direct deposition of sulphur and nitrogen oxides and other air pollutants directly on the earth's surface - were made in the vicinity of Bradford, Ontario. The results are being analyzed.

The Research Division's version of Fisher's Model was further improved and used to calculate Ontario Hydro's contribution to acidic deposition. This information is required by the Technical and Training Services Division.

Equipment and procedures acquired or developed over the past few years for measuring air quality around Lakeview TGS were transferred to the Technical and Training Services Division, which now performs this function.

Atmospheric Dispersion at Nuclear Station Sites

Techniques developed for studies of atmospheric dispersion at the sites of nuclear generating stations were applied at Darlington NGS, where SF_6 was released and its concentration monitored downwind by an array of samplers. A one-year dispersion climatology study of the Bruce area was also completed. Ontario Hydro's needs for mesoscale meteorological data were assessed, models for deriving such information were evaluated and a course of action was proposed.

Two dispersion models, one for puff releases and the other for continuous releases, were included in microcomputer programs for use in setting up the Pickering '85 nuclear contingency exercise. Versions of the model were transferred to Ontario Hydro and government representatives in the Provincial Nuclear Emergency Task Force for their use during the exercise and in other applications.

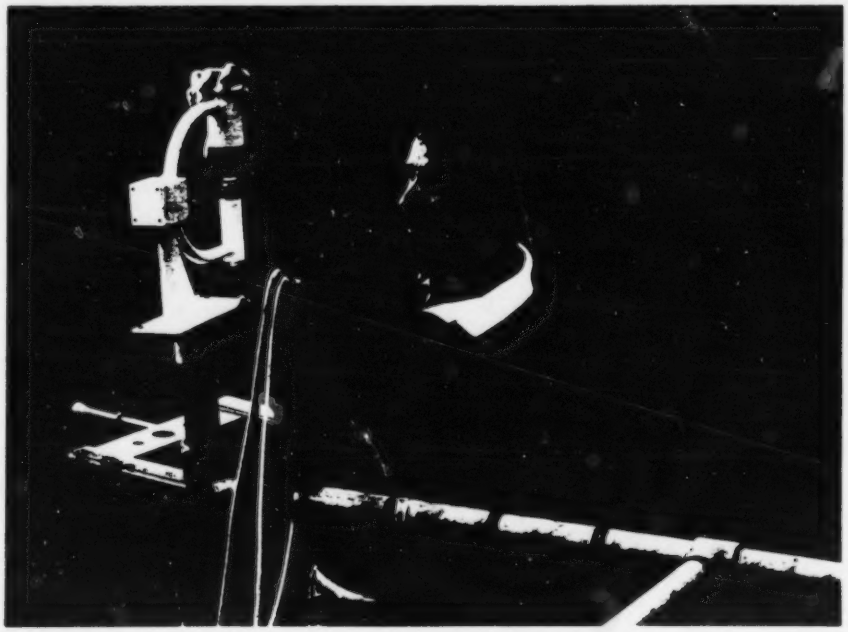
Improvement of Doppler SODAR

Sound Detecting And Ranging (SODAR) equipment based on the Doppler effect was upgraded through the acquisition and installation of transceiver and telemetering components of increased sensitivity, and the capabilities of the improved system were demonstrated. SODAR is expected to become the accepted technique for collecting upper-air meteorological data within Ontario Hydro.

Biological Conversion of Radionuclides

In support of the Canadian Fusion Fuels Technology Project, studies were continued of the biological behaviour of tritium released from nuclear generating facilities to the terrestrial and aquatic environments. Investigation of elemental tritium - a form expected to be emitted in minute quantities from the Tritium Removal Facility at Darlington NGS - showed that soil and leaf litter are the dominant sites in the terrestrial environment for microbial conversion of elemental tritium to tritiated water, the more radiotoxic of the two. Further investigation of the uptake and desorption of tritiated

A Lyman-Alpha hygrometer is being installed on a tower to determine the dry deposition rates of acid gases in an acid rain research program.



water in various aquatic and terrestrial species is expected to show little or no retention of tritium in the receptor organisms.

In related laboratory studies, the distribution of gamma radionuclides of cesium and cobalt in bottom sediments from the western basin of Lake Ontario is being determined.

The conversion of elemental hydrogen, deuterium and tritium to oxide forms is catalyzed by certain bacterial strains which can produce the enzyme, hydrogenase. Three of these strains were selected for laboratory evaluations of their potential for producing the enzyme under a range of growth conditions. Two of the strains produced high levels of hydrogenase when grown on a variety of organic substrates and are therefore suitable for mass cultivation on an economic scale. Elemental tritium, present as a contaminant in an atmosphere containing normal concentrations of hydrogen, was rapidly oxidized to tritiated water (HTO) by both bacterial strains. The optimization of culture conditions to maximize growth and hydrogenase activity is continuing. Several applications are possible for hydrogenase catalysis within the areas of fusion and fission technology.

Early in the spring, researchers began a study to determine the effects of growth regulators injected into the trunks of 12-year-old silver maple trees on the growth of sprouts. This work is part of a program to control tree growth under transmission and distribution lines.

Carbon-14 Studies

A laser-based process for enrichment of the carbon-14 ratios in ground water has been demonstrated in the laboratory, as part of work being performed in support of AECL's nuclear waste disposal program. The process will facilitate the radiocarbon dating of older ground water, which provides important information required in the selection of sites for nuclear waste repositories.

Assembly of a prototype cryogenic still for use in removing and concentrating the carbon-14 present in moderator cover gases and ion-exchange resins was completed and commissioning was begun.

Environmental Surveys at Generating Stations

Surveys were continued in the pre- and post-operational phases at Darlington NGS, Pickering NGS 'B', Bruce NGS 'B' and Atikokan TGS to assess the impact of the stations on the environment. Other studies of the distribution of fish schools and spawning of whitefish are in progress at the Bruce 'B' and Pickering generating stations.

WASTE MANAGEMENT

Concrete Cask for Irradiated Fuel

An integrated concrete cask is under development for the interim storage and transportation of irradiated nuclear fuel. Two half-scale models of the cask were constructed and tested. One underwent two drop tests and exposure to fire at 1000°C. The second was subjected to heat loads that simulated the decay heat of irradiated fuel internally and various ambient temperatures externally. Each model retained its structural integrity in

all tests. The design is expected to provide full containment of the irradiated load in the event of a transportation accident.

Permeability of Gasket for Irradiated-Fuel Cask

Krypton-85 and iodine-131 are two of the radionuclides that will be present in a stainless-steel irradiated-fuel cask being designed by Ontario Hydro. Both could permeate the cask gasket and pass to the environment. Because information on the permeability of the proposed gasket material is limited, permeation by the two species was determined at 60°C to 200°C in a gas chromatograph. They were found to be similar in behavior to the reference gas, helium.

Copper Containers for Nuclear Waste

Evaluation of copper as a container material for use in the disposal of irradiated nuclear fuel in hard-rock repositories is continuing. In tests thus far, copper has shown adequate integrity and durability as a barrier to the migration of radionuclei to the biosphere, and high resistance to corrosion in the most probable repository environment. Under worst-case conditions involving radiolysis and sulphide attack, however, corrosion rates increase and some pitting occurs. The project will provide corrosion data to AECL for use in overall appraisal of concepts for permanent disposal of high-level wastes.

Conditioning of Tritiated Aqueous Waste

When in operation the Tritium Removal Facility at Darlington NGS will generate quantities of tritiated aqueous waste that will require solidification and suitable packaging for its disposal. The waste package is the major barrier to tritium releases to the environment which must be less than 10^{-3} per cent of the original activity per day. The effects of the solidification medium and the container material and dimensions on the amounts of tritium release have been quantified as a basis for design of the package.

Solidification of Radioactive Aqueous Waste

Prototype equipment for the solidification of irradiated aqueous waste with a water-extendible polymer has been constructed and demonstrated. The equipment is compact and portable and can be operated either manually or automatically at a throughput of five litres per minute. Production models could be shipped to stations as needed rather than having a unit on hand at each station.

Characterization of Reactor Waste

In support of the development of facilities for the disposal of low- and intermediate-level wastes, the composition, activity level and radionuclide inventory of compactable reactor waste has been determined, and characterization of incinerable, non-processable and retubing wastes is continuing. This information will be essential for environmental assessment and licensing of future disposal facilities.

In-Ground Disposal of Low- and Intermediate-Level Wastes

Of various materials evaluated for use as backfill in the glacial till at the Bruce in-ground waste-management facility, a fluidized cementitious grout exhibited low viscosity, minimal phase-separation and shrinkage, uniform density after hardening, and adequate durability and strength. The grout fills voids and, when set, provides mechanical support for the waste packages. Studies are continuing of the effectiveness of the grout in controlling the release of carbon-14 and other radionuclides.

Sorption of Radionuclides by Normal and High-Density Concretes

Investigation of the permeability and radionuclide sorption of several types of normal and high-density concretes in cooperation with a West German research centre showed that the extent of microfracturing determines the permeability of concrete containers for storage of nuclear wastes. Sorption levels of plutonium and americium radionuclides varied considerably with the type of concrete, but were generally lower than desired. Future work will examine the use of geochemically active additives and aggregates to increase the sorption capacity of concretes designed for nuclear use.

Outdoor Storage of Irradiated Fuel Channels

A high-density concrete was recommended for the fabrication of modules for outdoor storage of irradiated reactor-fuel-channel assemblies removed from Units 1 and 2 of Pickering NGS 'A' under the large-scale fuel-channel replacement program. Because the structural use of high-density concrete as radiation shielding has been limited to indoor applications, little information was available on its performance outdoors. After laboratory testing and full-scale field trials, final adjustments were made to the mix design and placement procedures to assure proper quality of the end product.

Stresses in Ontario Rock Formations

In a project initiated by AECB and undertaken by Ontario Hydro, drilling and overcoring tests were made to investigate the magnitude and orientation of in-situ stresses and to assess seismotectonic conditions in sedimentary and crystalline rock formations. The data will help establish the risk of damage from seismic activity in eastern Canada.

A computerized borehole dilatometer was developed as an improved geological aid for evaluation of deep rock masses as potential sites for disposal of low- to high-level nuclear wastes. The ability of the dilatometer to operate at depth in small-diameter boreholes provides an economical means of determining deformation moduli, in-situ stresses and location of fractures in preliminary studies of a rock mass.

Thermal Modelling of Nuclear Waste Disposal Vaults

Experimental modelling of heat and

moisture diffusion around a theoretical, backfilled, high-level nuclear disposal vault was undertaken to predict temperature and groundwater regimes in the post-closure period of the vault. The behaviour of a clay-based buffer and a bentonite and sand backfill mixture will be evaluated under various simulated heat and groundwater flow conditions. Experience with the instrumentation, the design of experiments and the predictive procedure will be transferred to AECL for use in tests planned for their Underground Research Laboratory at Pinawa, Manitoba.

Geological and Geochemical Conditions of Oklo Natural Reactors

Information on the geological and geochemical conditions of the Oklo natural reactors in Gabon, Africa, has been gathered and evaluated for AECB in cooperation with the University of Western Ontario. The Oklo case can be applied as a natural analog for assessment of the validity of long-term conclusions reached concerning underground repositories for nuclear waste. The information has been useful in defining the optimum geochemical conditions for a waste repository and the limitations imposed by temperature, radiation, radiolysis and other influences.

Management of Waste from Limestone-Injection Process

In the limestone-injection process now under development for control of emissions from coal-fired stations, powdered limestone reacts with sulphur dioxide to form calcium sulphate, which is collected with the coal ash for disposal. In the development of procedures for management of limestone-injection waste, the chemical composition, reactivity and leaching properties of waste from a plant in Virginia and from preliminary trials at Lakeview TGS were determined. Treatment of the waste materials by the addition of water or ordinary fly ash to improve their leach resistance and physical strength was tested. Safe handling methods and environmentally sound options were developed and recommended for disposal of the waste.

Monitoring of Coal-Ash Disposal Sites

Monitoring in the vicinity of coal-ash disposal sites at the Domtar and Booth quarries and at Thunder Bay TGS and Atikokan TGS was continued through the year to ascertain the impact of ash placement on the quality of surrounding ground and surface waters. No adverse effects from leachates originating from the sites have been observed to date.

Removal of PCBs from Insulating Oils

Performance testing of a 6000-litre-per-day trailer-mounted dechlorination facility for the removal of low levels of polychlorinated biphenyls (PCBs) from insulating oils neared completion and final government approval of the equipment and process was awaited. Treated oil from the dechlorination process is suitable for re-use in transformers and capacitors. Treatment provides a preferred alternative to long-term storage of contaminated oils. A non-exclusive licensing agreement was signed with a Canadian company for rights to use the process in Canada. An agreement is being negotiated with a second company for rights to the US market.

Reclamation of Downgraded Heavy Water

Laboratory investigation showed that use of a fixed carbon bed would be effective in the reclamation of heavy water from 41 000 kg of downgraded stock containing a persistent oil emulsion that could not be removed by the existing clean-up train at Pickering NGS. The process should yield for re-use about 5000 kg of nuclear-grade heavy water valued at $2 million.

AQUATIC STUDIES

Repulsion of Fish from Station Water Intakes

Work continued on several systems for the guidance and repulsion of fish which at times clog the water intakes of generating stations. By altering fish behavioural patterns, some of these systems also have potential for use in commercial fisheries operations.

A Hidrostal fish pump and transport system was effective in passing, unharmed, pelagic fish species in the forebay at Pickering NGS and American eels at Saunders GS. The effectiveness of air bubbles as an alewife excluder was improved with the addition of strobe lights.

Pneumatic poppers, a sonic deterrent, effectively repelled alewife from the fish diversion structure at Pickering NGS. In work funded by the Empire State Electric Energy Research Corporation two mechanical sonic devices – a fish drone and a fish pulser were developed. These devices are more reliable than pneumatic poppers and have superior acoustical characteristics. During preliminary tests at Lennox TGS and Pickering NGS, both devices showed promise for excluding pelagic species from the intakes of generating stations.

A sonar-based system has been assembled that automatically activates deterrent devices as fish densities increase. Field trials of the system, which comprises mainly an acoustic transceiver and signal switching and integrating components, have begun.

A Model Benthic Sled

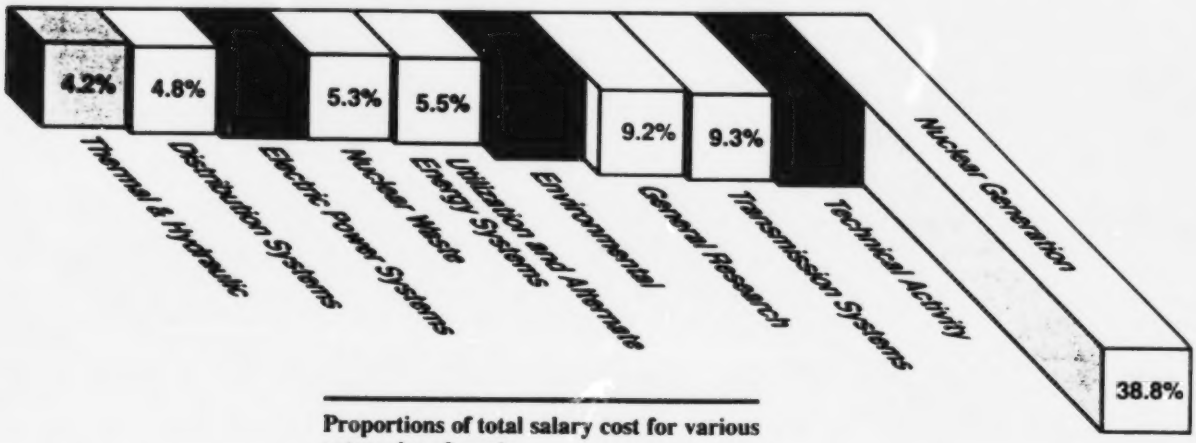
Periodic counts of benthic fish larvae can provide a good measure of the effects of generating-station operation on bottom-dwelling species. The effectiveness of a laboratory-scale benthic sled for the capture of round whitefish larvae was tested in a 15-m-long flume. The sled was effective in capturing larvae on a smooth, concrete bottom, but much less so on a more typical irregular, fine-cobble bottom. Success was better under twilight conditions when larvae commonly rise several centimetres off the lake bottom, and this suggests that night operations may improve the likelihood of capture. It was noted also that most larvae in the flume become detached in currents greater than 10 cm/s, resulting in a large catch. This suggests that drift nets placed on the bottom would likely be effective in capturing whitefish larvae displaced by lake currents.

Resources and Costs

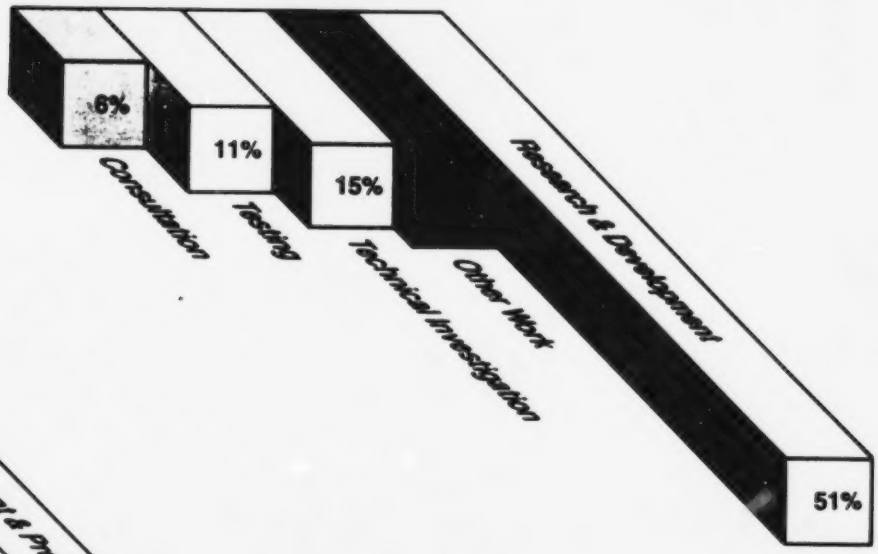
At the end of 1985, the Division's personnel resources consisted of a total regular staff of 621. The administration and organization of staff are shown on the opposite page.

The distribution of staff in broad occupational classes and its application in various categories of work (Divisional Services Department excepted) are shown below.

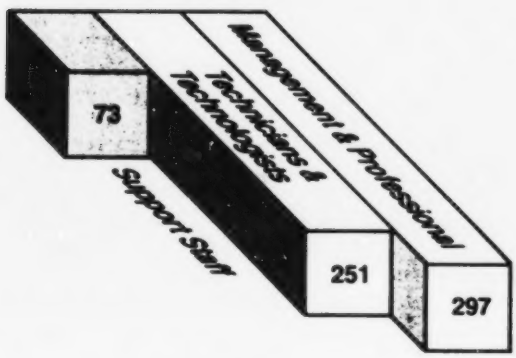
Research Division Programs for 1985 - Proportions by actual gross cost



Proportions of total salary cost for various categories of work



Occupational classification of Research Division staff

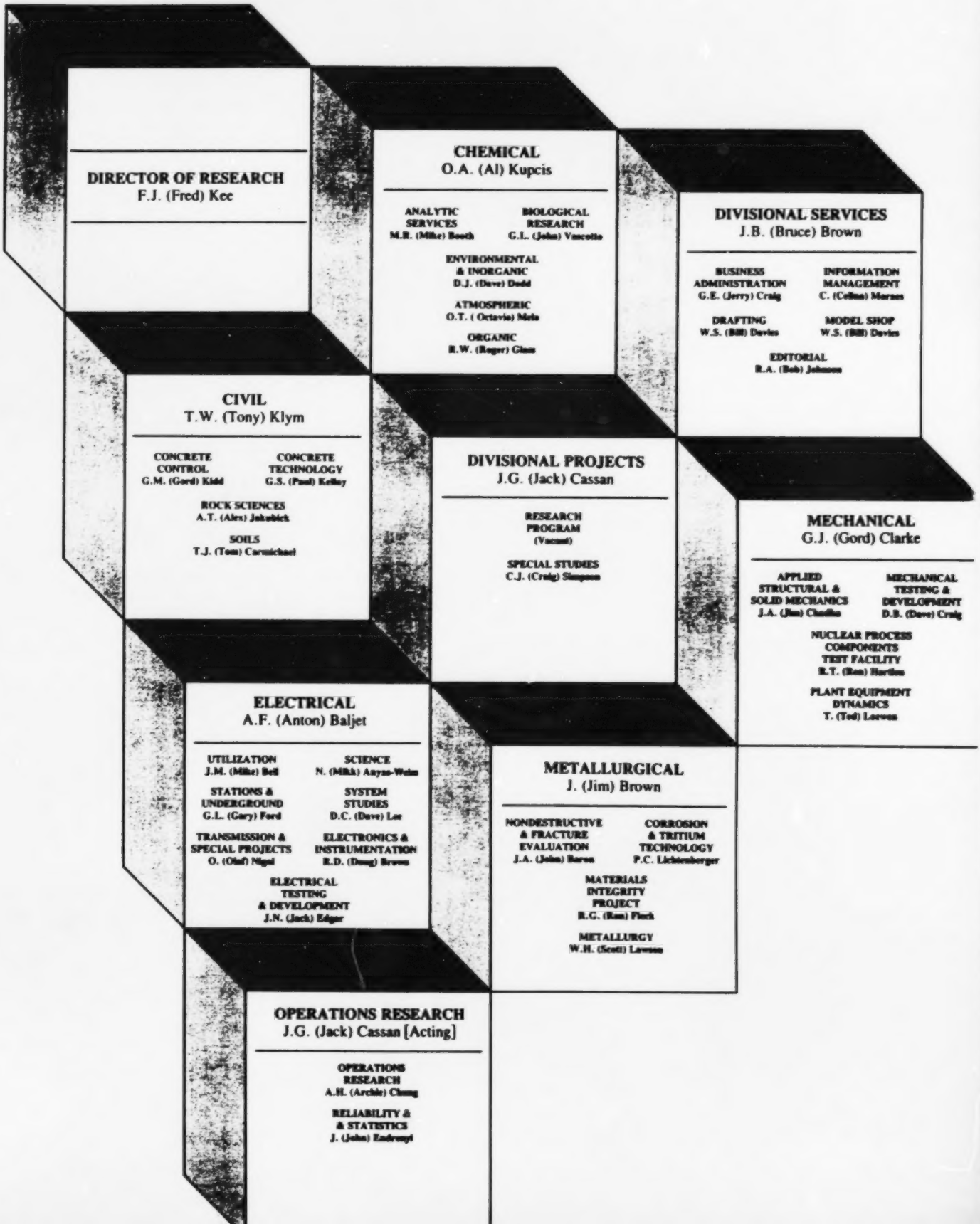


The total of all costs, including those for space, material and equipment for work done by the Research Division in 1985 was approximately $50.1 M.

Costs were met or allocated as follows:

Revenue from work done for other organizations	4.0M
Transfers to other Ontario Hydro Branches	22.6M
Transfers to the Cost of Power	23.5M

Organization



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Abbreviations and Acronyms

AECB	Atomic Energy Control Board (of Canada).
AECL	Atomic Energy of Canada Limited - the crown corporation that developed the CANDU system
AERE	Atomic Energy Research Establishment (of the United Kingdom Atomic Energy Agency).
AMEU	Association of Municipal Electrical Utilities -the utilities to which Ontario Hydro supplies power
ANSI	American National Standards Institute.
ASTM	American Society for Testing and Materials.
CANDECOM	A process developed by Ontario Hydro and AECL which uses a dilute, regenerable solution to decontaminate the interior surfaces or nuclear-reactor systems.
CANDU	Canada Deuterium Uranium - a nuclear reactor that uses deuterium oxide (heavy water) as moderator and as heat-transport median and natural (unenriched) uranium as fuel.
CEA	Canadian Electrical Association - an association of electrical utilities that is dedicated to the development of policies and programs for the production and distribution of energy with an optional combination of environmental effects and user benefits.
COG	CANDU OWNERS GROUP - AECL and Ontario Hydro and other electrical utilities with interests in the development and operation of CANDU units.
EPRI	Electric Power Research Institute - a national organization for research and development supported by electrical utilities in the United States.
GS	Generating Station - The term without a descriptive prefix is used for hydro-electric stations on the Ontario Hydro System. The oldest has been in operation since 1898.
IEEE	Institute of Electrical and Electronics Engineers
IREQ	Institut de Recherche d'Hydro-Québec (Research Institute of Hydro-Québec).
NGS	Nuclear Generating Station.
TGS	Thermal Generating Station (fossil-fired)

SIGNIFICANT RESEARCH CONTRIBUTION

This programmable controller, designated the OH-180, is one of several microprocessor-based devices designed and developed by the Research Division and manufactured by Canadian industry in the quantities required by Ontario Hydro for use on the power system. In Darlington NGS, for example, some eighteen hundred OH-180s will be used as compact substitute for myriads of electromechanical-relay panelboards and control-wiring connections. Although projects like this one are undertaken in support of the power system, Canadian manufacturers benefit from the resulting transfer of technology through broadening of their manufacturing expertise, and development and pursuit of new marketing opportunities.